Metallurgical and Chemical Engineering

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Electrochemistry in America

"There is a divinity that shapes our ends, rough hew them how we will." This quotation from Shakespeare which E. G. Acheson has placed at the head of the story of his life, might well be used as the leitmotif of a history of chemistry in America by any one who has the courage to write it. But who would in these days when history is in the making and American chemistry is expected, as never before, to solve problems and do things? Yet just because a detailed review of the many things that have happened during the past year in the different branches of the American chemical industries is inopportune now, the moment seems to call for a rough perspective sketch of at least a few tendencies which have been active in the shaping of American chemistry. If inspiration such as past achievements can give, is needed now by American chemists, it could not be found anywhere more markedly than in the story of American electrochemistry. No other branch of industrial chemistry has so distinctly the smack of American soil, shows so clearly the individuality of American conception and execution, as electrochemistry.

The story of American electrochemistry comprises not much more than the last two decades. Yet like anybody who is anything, American electrochemistry has a past. Without making impossible claims of impossible ancestors, we will mention one single name—Robert Hare of Philadelphia. He is perhaps most widely known as the inventor of the oxyhydrogen blowpipe, about which he presented a paper in 1801 before the Chemical Society of Philadelphia (by the way, the first chemical society in the world). But his influence was even broader in that he was the earliest American scientific experimenter and discoverer in electrochemistry. Hare interested himself in improvements in primary batteries. He introduced his "deflagrator" concerning which we quote from Silliman (from the delightful chapter on Hare in Edgar F. Smith's "Chemistry in America"): "Although the discovery of the constant battery by Daniell and of the double combinations of platinum or carbon with amalgamated zinc and nitric acid have rendered the old forms of this instrument no longer as useful as formerly, it is not less a proof of the merit of Hare's apparatus that Faraday, in 1835, after having exhausted his ingenuity and experience in perfecting the voltaic battery, found that Hare had already, nearly 25 years before, accomplished all that he had attempted, and with a noble frankness, worthy of all praise, he at once adopted Hare's instrument as embodying the best results then possible."

But even more remarkable is what Robert Hare was able to accomplish with his primary batteries as only

source of current. He improved Davy's electrolytic apparatus and process for obtaining the amalgams of calcium, barium and strontium from their chlorides. And he built an electric furnace which was the first electric furnace ever constructed and employed. Dr. C. A. Doremus presented an interesting paper on this furnace a few years ago before the American Electrochemical Society and the claim has been made that Hare must have produced in his electric furnace calcium carbide, phosphorus, graphite and metallic calcium. Whether he did or not, really matters little. But if he did, the question suggests itself: why did it take some 70 or 80 years to rediscover those substances and make them industrially?

One reason would be rather obvious. It is almost getting tedious to repeat that electric power cost is usually a large item in the cost sheet of electrochemical processes. With primary batteries as the only source of current, any development of industrial electrochemists and of electrical engineering in general was a clear impossibility. But when the dynamo made its commercial appearance it was quite natural that electric lighting and the mechanical applications of electricity such as traction and power transmission and distribution, first attracted the inventive talents of electrical engineers. Only after they had succeeded it became possible for the electrochemist to step in.

The work of the electrochemist is directed toward two aims. One is the production of electrical form chemical energy, the other is the reverse problem, the production of chemicals and chemical effects by electrical means and the storage of energy in chemicals. In the former field nothing that has the faintest resemblance to a revolutionary advance has been made in the design of the primary battery, which is still essentially based on the use of zinc as "fuel." The carbon battery is still a mere dream. Storage battery engineering, on the other hand, has passed with success through an extremely active career. In the development of the lead storage battery Brush in this country, like Faure abroad, devised in the early eighties of the last century an important improvement in the Plante lead cell consisting in the application of active material to a conducting support. Many smaller improvements in the lead cell have since been made by uncounted American battery engineers. But the only radical departure has been due to Thomas A. Edison, who invented and developed the iron-nickel alkaline storage battery.

Nor is this by any means Edison's only contribution to electrochemistry. Edison's revolutionary pioneer work on the carbon filament for the incandescent lamp was intrinsically of a chemical nature. All our modern illumination methods are essentially based on chemical research. And the indirect influence which Edison's personality has had on the evolution of American electrochemistry in shaping the career of such men as Acheson cannot be overestimated.

For this reason a few words may be said on Mr. Edison's well known method of working or procedure in invention, because in a way it is characteristic of the methods of working of the few big early electrochemical inventors who became the founders of the modern electrochemical industries of this country. Edison's principle is to take nothing for granted, to try everything, every material and every method—whether apparently possible or impossible, practical or impractical, probable or improbable—and to observe with utmost care in any case what happens. "Inspiration is only another way of spelling perspiration" is one of his slogans.

After all, this method of working is the only method possible in a new field in which there are absolutely no analogies to go by. This method was the only one possible in the pioneer work which led to the foundation of the big industries of carborundum and alundum, artificial graphite, calcium carbide, and so on, in the electric furnace.

When the electric furnace had been invented it was a tool to be used and abused. A very distinguished electrochemical inventor once said that it was all foolishness to rely on theoretical principles in high-temperature electric-furnace work, as there were neither analogies nor quantitative figures available. All that could really be done was to try an experiment and see what comes of it and observe whether the product is good for anything. This may sound a little rough, but it states the case truthfully with utmost frankness and it emphasizes in a very modest way the requirements in the mental make-up of an experimenter who proceeds along such lines. He must have the faith of a child, the courage of the pioneer who blazes the trail, and a power of keenest observation of the smallest indications of usefulness which appear in his experiments and which then become his guide for further work. Each of these mental requirements is rare, their combination is given to very few.

Acheson's glorious life work is a fine illustration of the momentous scope of various industries which, in the hands of a strong individuality, may grow with almost logical necessity out of a single and apparently exceedingly simple chemical reaction—in Acheson's case the reaction between silica and carbon. Acheson carefully noted anything he found in his carborundum furnace. And when he found something that was what it should not be, it was not despised as an undesirable impurity (which it would have been to an ordinary manufacturer), but it became to Acheson an indication of what would happen under changed physical conditions and a guide to new work. Thus the carborundum industry was followed by the industries of artificial graphite, silicon and siloxicon.

It is evident that work of this kind which creates new industries can only be carried through to success by strong individualities which naturally become a source of inspiration to others so that their work becomes a nucleus around which the work of others on a broader field crystallizes. Thus we have the early pioneer work of the two Cowles brothers which led to experimental work in many fields and to the industrial manufacture of aluminium alloys and other alloys in the electric furnace. And as a further perhaps purely psychological result, Cleveland became for a time an active center of electrochemical endeavor. Thomas L.

Willson, of calcium carbide fame, was once in the employ of the Brush Company in Cleveland, and Edward R. Taylor, the inventor of the carbon bisulphide electric furnace, also belongs to the group of old independent Cleveland electric-furnace men. Herbert H. Dow worked out at the Case School his process for sodium chloride electrolysis, and David H. Browne successfully separated nickel and copper from Sudbury ores for a series of years by an electrolytic process at Cleveland. And Cleveland is still the home of the amorphous carbon electrode industry, although the largest electrodes for electric furnace work are now made at Niagara Falls.

In fact, the chief center of electric-furnace activity in this country and in the world is now Niagara Falls. There we have the big electric-furnace industries of artificial abrasives, of calcium carbide and calcium cyanamide, of phosphorus, of silicon, and so on; of electrolytic-furnace processes we have the Hall aluminium process and the Castner sodium process, of electrolytic processes the manufacture of caustic and chlorine on a very large scale, of chlorate, etc., almost all processes used there being products of American genius. There are very few imported processes in use at Niagara. And it is but the plain truth to say that the Niagara Falls electrochemical plants demonstrate in broadness of scope and detail of execution in the highest degree the application of the American type of industrial genius to chemical industry.

While we are writing these lines, the news reaches us of the death of Charles M. Hall on December 27 at Daytona, Fla., where he had gone a few months ago in the hope of final recovery from a sickness of several years. Thus Hall has followed shortly Heroult, his friend and competitor in aluminium fame, into eternity. Hall in this country and Heroult in France invented simultaneously and independently the process by which aluminium is now made. And to Hall belongs the credit for having started the electrochemical settlement at Niagara. When in 1893 the Niagara Falls Power Company completed its power house the next step of finding customers for the power was not so easily solved, until the Pittsburgh Reduction Company with the Hall aluminium process broke the ice. How one after the other electrochemical industries followed is history.

It is impossible to go any more into details. Only with respect to the electrolytic production of caustic and bleach—a very flourishing industry just now since on account of the European war the importation of European bleach has stopped—we may point out the abundance of processes in successful commercial use. For the diaphragm process Le Sueur and Dow were early pioneers in this country, while probably the latest cell of this type is the German Billiter-Siemens & Halske cell, in use by the Niagara Alkali Company. The Pennsylvania Salt Company uses the Gibbs cell at Wyandotte. The mercury cathode process is represented by the Castner-Kellner cell in use on a large scale by the Castner Electrolytic Alkali Company at Niagara Falls. Analogous in principle to the mercury cathode cell, but using a fused electrolyte and a fused lead cathode for alloying with the sodium, was the ill-fated Acker process at Niagara. The Townsend cell is of decided originality; while it is usually classed as a diaphragm cell, it is really much nearer the mercury cathode cell, since the caustic soda as soon as formed is carried away by kerosene; in its development on a large scale for the Hooker Electrochemical Company at Niagara, Dr. Baekeland, among others has distinguished himself.

In the problem of the fixation of atmospheric nitrogen the credit of having done the pioneer work belongs to Bradley and Lovejoy, though their plant at Niagara was finally a failure. While the technical efficiency of output per kilowatt-hour in their process was practically the same as it is in the successful Birkeland-Eyde process in Norway, the question of commercial success turns on the cost of power and the power cost at Niagara is four or five times that in Norway.

But another application of electrochemistry to gas reactions, also of American origin, is proving a big industrial success in this country. The Cottrell process of precipitating dust and generally any liquid and solid particles from fumes and gases, now finds a steadily widening field of usefulness in smelters, refineries, chemical works, gas, cement and general industrial plants.

We have not even touched yet on the immense field of the applications of electrochemistry to metallurgy. But this is "another story" that may be left for another occasion. Surely even in the limited field we have considered, American electrochemists have shown that they stand on their own feet and can create industrial empires. When this country needs the help of the chemist —and this will be more and more the case—American chemists stand ready to do their duty.

Progress in Gold and Silver Metallurgy in 1914

As one of the most suggestive developments of the year we note the remodeling of the Dome mill, in the Porcupine district of Ontario. With the increase in reserves and the coincident decrease in grade of the ores of this mine, the milling capacity was largely increased and the flow-sheet rearranged to accommodate the lower grade ore to be treated. These conditions were met, as, in our opinion, they must always be met, by discarding all-sliming and supplementing the slime treatment with the installation of sand vats, a portion of the concentrates being reground in tube-mills.

Fine grinding, as with tube-mills, has done much for the advancement of the metallurgy of gold and silver, as indeed it is now doing for almost all concentration projects, of whatever metal-bearing ores. It has fairly won its place as standard practice and must continue to be a part of every scheme of treatment. But we have sometimes thought that our American metallurgists have been overzealous in their quest of the maximum extraction, and that fine grinding may at times have been unwisely developed to the extreme of total sliming. Tube-milling, particularly when carried to the point where all-slime treatment may follow it, is an expensive operation, and as the grade of the ore decreases, the in-

creased recovery due to the reduction in size of the particles may very well fail to offset the cost of power, material, and attendance expended for the reduction.

We think it may fairly be said that the lower the grade of the ore, the greater difference will exist between the maximum percentage of extraction obtainable and the maximum economic extraction, and that the latter will be lower as the grade of the ore is lower.

Briefly, we consider the work at the Dome to be soundly conservative; and from it we turn to examine, with interest, the radicalism of Mr. Jackling, as exemplified in the proposed Alaska Gold Mines mill.

Perhaps no work of recent years will be watched as closely by metallurgists as will this application of the accepted practice of the porphyry coper mills to the requirements of gold metallurgy. Breaking is to be followed by rolls, roughing tables, classifiers, regrinding plant, and concentrators, the aim being for concentrating efficiency rather than high recovery by amalgamation. Revolutionary as it seems, it may be inspired, and certainly not only the prestige of its sponsor but many strong features of the process itself merit the attention it will receive. To the onlooker this undertaking is particularly timely, since the increase in the falling weight of stamps has ceased, both abroad and in this country, where we understand that tests by one of the largest producers have indicated 1250 lb. as maximum falling weight obtainable without loss of efficiency.

With the continued development and widening application of cyanidation, amalgamation has in many instances been abandoned; in many others reduced to a position of minor importance. It is said that a good mine is a long time in aying; the same may be said of a good process, and r feel that amalgamation, far from being moribund, has its distinct field, doubtless narrower than formerly and yet of sufficient consequence to justify its consideration as a live process.

We note, in fine grinding, a drift toward shorter tube-mills, which has doubtless been influenced by the well-merited success of the Hardinge conical mill.

In the treatment of slime, undoubtedly the most interesting development of the year is the steady increase in the number of plants using continuous counter-current decantation for washing and dewatering slime This process, which at the time of its first application by John Randall failed through the unsuitability of the mechanical devices then available, has now, with the development of dependable slime-thickening tanks, fairly won a place beside the filtration processes, and is said to be doing most effective work. We look for its further development during the coming year

In precipitation, zinc, whether in the form of dust or shavings, but with the former making constant gains, continues to be generally used. The aluminium dust process, as used at the Nipissing low-grade mill, has brought forward the first innovation in this branch of the science which has come to the point of continuous and successful operation.

Conditions may no doubt exist where this precipitant, even though more expensive, has strong claims to superiority, but in our judgment they will be comparatively few and in all likelihood will be confined to ores where silver is the dominant metal, as the comparatively high alkalinity which is essential to the method would in certain instances inhibit extraction from gold-bearing sulphides. Broadly speaking, the process follows the general scheme used in precipitating with zinc dust, which has become the standard American method, except in small installations.

Passing from the metallurgy of gold, we consider the progress in the treatment of silver-bearing ores, in so far as the two metals may be considered separately.

Here we find the most interesting work of the year in the methods of the Nipissing mills, where the aluminium precipitation method, already discussed, is accompanied by the very interesting desulphurization method of Denny, wherein the ore, in a solution of sodium hydrate, is agitated in the presence of aluminium plates. As if this were not enough, the amalgamation method of their high-grade mill (although this perhaps antedates the period under review) is a further contribution from this source. All these innovations illustrate the constant widening of the field of cyaniding and the possibilities still awaiting the careful investigator.

In this connection we feel that the paper by Mr. G. H. Clevenger, in the July *Bulletin* of the American Institute of Mining Engineers, merits most careful reading by all metallurgists, as an illuminating and thoughtful article, delightfully sane in its consideration of the questions which it discusses, and, indeed, well worthy of the best traditions of the Institute.

In the course of this discussion, Mr. Clevenger expresses his satisfaction that, in the desulphurization process to which we have already referred, some one has at last brought forward a process depending upon reduction, as a foil to the innumerable oxidation methods now extant. We might continue the thought and express to the able staff of the Nipissing our appreciation of their efforts to give us some really valuable contributions to the development of the chemical side of cyanidation, which, coming as they do after years when all development seemed to be along mechanical lines, are more than welcome.

Chloridizing-leaching, as practised at Park City, and described by Mr. Theodore P. Holt, is another interesting contribution to the year's technology. The chloridizing roast is given in the Holt-Dern roaster, at a cost of less than $0.17 per ton, and the total cost of milling is placed at not over $1 per ton, with extractions of gold, silver and copper above 90 per cent.

In the technical press, two interesting controversies have continued their perennial course. The estimation of tonnage by specific gravity methods has grown in popularity, owing to its simplicity and cheapness. The experience of the Nipissing mill, cited by Mr. Johnston, confirms this view. He shows that the determination of weight, taken by a registering scale on the ore as it entered the mill, was checked over a period of seven months against the usual method of specific gravity tonnage determination, during which time a variation of only one-eighth of 1 per cent was noted. From this it seems reasonable to conclude that an intelligent application of the specific gravity methods can be depended upon for accuracy.

Not so satisfactory has been the discussion of the work of crushing, wherein the advocates of the laws of Rittinger and of Kick have belabored one another with hypotheses and equations innumerable. The struggle still rages, and we think that comment may well be deferred until next year.

In the line of assaying, Dr. Dewey has called attention to the revival of a method of directly determining silver in gold bullion, avoiding inquartation by alloying with cadmium, dissolving in nitric acid and titrating with standard sulphocyanide solution. This method, suggested by Balling and developed by Whitehead, had been lost sight of until revived at the San Francisco Mint, from which its use has been extended by the Mint Bureau.

Copper Metallurgy in 1914

Copper, more than any other metal, has been seriously affected by the European war. Many mines and some reduction plants are entirely closed, and mines and plants that are still operating are doing so under greatly reduced capacities, their output being about half the normal. At the beginning of the war an approach to a panic was noticeable among copper producers; all experimental work was discontinued, and betterments stopped. Gradually a feeling of confidence and security has been developing, and while the great foreign market for copper is still closed, yet with the establishment of equilibrium between production and domestic demand, a price has again been fixed which is very likely to be maintained.

Progress in copper metallurgy, during the past year, has been along the lines of the further application of flotation methods to the dressing of ores; of coal-dust firing to reverberatory smelting; increased activity in hydrometallurgical treatment, and the utilization of by-products.

By use of pulverized coal great economies in reverberatory smelting are accomplished. A greater tonnage of ore can be put through the furnace, a cheaper fuel can be used, a more complete combustion effected. Stoking and the handling of ash are eliminated. Furnaces of much greater size are possible; hence a more perfect separation of matte from slag is secured.

We are told of plans for building reverberatory furnaces with hearths 25 ft. by 175 ft. Coincident with the completion of these large reverberatory furnaces will be the blowing-out of blast furnaces, reverberatories being given the entire work of smelting all grades and kinds of ore. This means a marked increase in the percentage of copper on the charge, as concentration will be practiced to a much greater extent than formerly. By the adoption of oil flotation methods the losses in concentration, which occur mainly in the slime, will be very greatly reduced; and the cheap preliminary mechanical concentration, hitherto prohibited on first-class ores because of such losses, will be universally applied, except to self-fluxing ores. Another advantage of this plan will be that the large tonnage of limestone required under blast-furnace treatment of first-class, highly silicious ores, will be reduced to a minimum, for the concentrator will furnish a practically self-fluxing product and only enough lime will be added to the charge to produce a more desirable slag than the ferrous silicate furnished by the ore alone.

The practice in converting leady copper-matte, recently adopted at the Tooele plant of the Anaconda Copper Mining Company, is exceedingly interesting and may have a wide application. Under the old method of adding to the molten matte, in a basic-lined converter, sufficient silicious material to produce the standard slag, the fume passing to the bag-house was very corrosive and bags were destroyed to an extent that was practically prohibitive. The superintendent conceived the idea that a remedy might be found in converting in the absence of silica. This was expected to be accompanied by a building up of magnetite inside the lining, consequently limiting the life of each converter. Contrary to expectation the lining does not build up, and in addition a more complete elimination of lead and zinc is effected, together with the production of a fume which is non-corrosive to the filtering bags. To effect as complete elimination of lead and zinc as possible, the charge is over-blown, and as a result the basic slag is rich in copper. Both slag and matte are then transferred to other converters where, in contact with fresh copper matte, the final converter slag is brought down to a relatively low copper and silver content. This slag, of course, is re-treated as is usual with converter slags.

Efforts in the hydrometallurgical treatment of copper ores have been directed largely to methods of precipitation of the copper from solution. Preference seems to be in two directions: electrolytic and metallic iron precipitation. The former has many claims for first place, particularly because it furnishes a product that is at once commercial and requires at most only a furnace refining. The question of the production of foul solutions which complicate electrolytic precipitation in many cases is a serious one. The new plant at Chuquicamata is expected, according to recent reports, to produce electrolytic copper so cheaply that it can be placed on the European market at a price not exceeding 6 cents a pound.

Precipitation with metallic iron produces an impure cement copper, but this is of little moment when the leaching plant is connected with or near to a smelting plant. The amount of scrap iron is limited and a large plant will of necessity be compelled to seek some other source of metallic iron. Sponge-iron produced by reduction at relatively low temperatures, far below the melting point of iron, is an effective precipitant and will be largely used. Such iron can be made at a cost not greatly in excess of the cost of scrap iron, and with improved methods this cost may be still further lessened.

For some years a few smelters have been making arsenic in limited quantity, and much more would be made were there a market for the product. Cottrell fume-precipitation plants have been placed in successful operation at several smelteries and an exceptionally large one is planned for Anaconda. It is also planned to greatly increase the capacity of the Anaconda sulphuric acid plant, one unit of which was completed this year, so that not only will sufficient acid be produced for all hydrometallurgical needs, but also for the manufacture

of phosphate fertilizers. An attempt will be made also to save metals other than gold, silver, and copper, which have been the only ones heretofore receiving attention in copper smelteries. It has been found, further, that brick of a beautiful buff color can be made from tailings.

Status of Zinc Metallurgy in 1914

In reviewing the year 1914 in its relation to the metallurgy of zinc, the effects of the war greatly overshadow other considerations. The industry was not in a flourishing condition before the outbreak. The first half of 1914 had been a period of low metal-price, with small and uncertain margins for the zinc smelters. This was due in general to the business depression, and in particular to an increasing metal stock with irregular demand; to an uncertain ore supply and the stagnation in the iron and steel industry. When war was added to the existing burdens and uncertainties, managers and executive committees found it necessary to give almost undivided attention to finances, metal-price fluctuations, changing ore supplies and plant economies. There was so wide a disagreement as to the probable market position of the metal that metallurgical experiments and improvements were quite generally restricted, deferred or abandoned. Until the end of the war can actually be seen, it seems likely that, although better metal prices may obtain, and the situation look brighter for both miner and smelter, not much new work will be started.

In the smelting or metal-producing end of the industry, there have been, nevertheless, several interesting developments during the year. One was the tendency of the sponsors of those electric and electrolytic processes which have had more or less successful laboratory trials, to locate their first small commercial plants near the Mississippi River power supply. Although one of the chief aims and reasons for these processes— elimination of freight charges on low-grade ore—is thus ignored, there are other factors which outweigh this consideration, at least for these trial plants. They are cheap power, fuel, labor and supplies; a variety of ores and furnace products from which to choose; good transportation and near-by markets for products.

This tendency is being opposed by an active effort from a new source. The hydroelectric power companies of the Western mining states, in an attempt to equalize their irregular power load and to build up new business in mining regions at present inactive, have not only offered direct inducements to mining companies known to be considering electrolytic processes, but have sent into the field a staff of their own experts to work on processes and methods supposed to be suitable. This may perhaps be termed a flank attack on the complex-ore situation, and at least offers possibilities in the way of securing the best available apparatus, in marketing some by-products, and even in providing some financial assistance.

No radical changes in the retort-smelting of zinc ores can be chronicled. The year's record is again one of many small improvements in details of construction and operation.

Several of the American zinc smelting companies are now regularly marketing zinc dust which, as a precipitant of gold and silver in the cyanide process, is steadily replacing zinc shavings made from sheet metal. Zinc dust has heretofore come largely from Germany, the imported dust being considered more desirable than the domestic product on account of greater uniformity, both physical and chemical. Having had the market for this material practically forced on them, American managers quickly arranged to supply it and are rapidly learning to turn out a satisfactory product.

Improvements in methods of handling retort residues at the zinc furnaces have brought about such an increased commercial saving of gold, silver, lead, and copper from Western mixed ores, and have made results so regular and dependable, that such ores are now commonly purchased under sliding-scale schedules providing payment for all valuable metals contained. This has already made profitable several Western mines heretofore operated at a loss or not at all.

The fact is well known that not only do the residues from retort furnaces carry most of the gold, silver, lead, and copper in shape for recovery by lead or copper smelting, but so also do the residues from zinc-oxide furnaces. Many proposals to use the oxide furnace as a preliminary igneous concentrator have been made, and trials have proved that it is metallurgically possible. Economic factors, however, have made it questionable whether such processes will succeed if placed near the mines, where they are most needed. It would seem as though there must be favored locations where such methods might succeed. A beginning was made at Leadville during the year, and some progress reported; but at least another year will be necessary to determine the real possibilities of the plant.

In the mining and milling end of the industry, in which the ore producer is more directly interested, and seems likely to be for some time to come, there is not much positive and completed improvement to record. Wet concentration has advanced only in minor details. Some new work of interest has been done with dry concentration, but results cannot be said to be final. Magnetic and electrostatic separation hold their own in a field that does not seem to widen much. Chemical methods made little progress except along electrochemical lines. The work begun in chlorination in the Coeur D'Alenes is claimed to be very promising, but success is not yet a certainty.

The one really active process is flotation, and here the interest and work are widespread. It is unfortunate that the patent situation is so unsettled, because many really important discoveries are not being given publicity. This is particularly true with regard to selective methods aiming at separation among the several sulphide minerals. When once it has been definitely settled how far the claimed fundamental patents extend over the industry, it is certain that progress will be much more rapid. Enough is known now to make it certain that flotation can be made selective, but the degree of success and the methods to be employed will not be revealed for some time to come. While this is truly un-

fortunate from the standpoint of the mine operator, it nevertheless points decisively to the fact that flotation as a whole is by far the most important, inclusive and promising of any of the preliminary methods; that it is getting widespread and competent attention, and is certain to attain extensive application.

The Steel Trade's Poor Year

The year just ended has been the worst, from a commercial standpoint, that the steel trade has passed through since 1898, the last year of the great industrial depression. Production has been exceptionally small, about 60 per cent of capacity, while prices realized have been at the lowest average level since 1898.

The steel trade is distinguished from many other industries by the facility with which it makes remarkable records. It is, as Andrew Carnegie used to remark, either a prince or a pauper, though why he should be the man to say so is not so easy to fathom. Perhaps the one aspect mentioned represents his experience and the other his observation. There are some good reasons why the steel trade should experience violent fluctuations. One reason commonly assigned is that its products go very largely into permanent construction, but the volume of construction work in general hardly exhibits the wide variations that are observed in steel making activity, and the proportion of steel output that passes into current daily consumption, as in tin plate, for instance, is quite large.

The principal cause of the fluctuations in the steel trade is that stocks are carried by buyers and are not carried by sellers. The buyer is speculative to an extent. He anticipates his requirements when he thinks the market is going to advance and thus he helps to cause the advance. He curtails his stocks when he observes the market is declining and thus he encourages the decline. The buyer's conduct by no means represents pure speculation, for the nature of steel mill operations is such that when orders are plentiful long runs on a given size are specified for the individual mill and deliveries are made slow, while when orders are light rolls are changed or reset for the small specification and shipments are made promptly. As the mills grow busier the buyer must increase his stocks, as he can depend less upon the mill for quick shipment of the sizes and descriptions of steel he may need, while as mill activity decreases the reverse is the case. The average stocks of steel in the country are large, running well into the millions of tons and distributed in many quarters from the large jobbers' warehouses down to the country blacksmith, and the fluctuations from large stocks to very small stocks are necessarily counted in the millions.

There are other industries in which buyers carry stocks in widely varying amounts, but in such industries there is usually the opportunity for the producer also to carry stocks upon occasion. Copper is a highly speculative metal and buyers carry large or small stocks upon occasion, but the copper producers can readily carry stocks themselves, continuing production at an economical pace and withholding the product from the market. The steel manufacturer cannot do this, except in a few instances. Wire products, nails, fence, etc., can be stocked, and some descriptions of tubular goods can be stocked to an extent. Tin plate formerly could be, but sizes have been so multiplied that stocking is risky. Rails, bars, plates and structural shapes are not stocked, there being no standard sizes and specifications to which the mill can work to advantage. In the case of sizes that are common the cost of storage and rehandling would be unreasonably large.

The extreme leanness of the past year in the steel trade was due to a combination of circumstances. A rhythm of ups and downs had been established, but special conditions operated to make the trough in the curve particularly deep and wide. After the period of great activity ending late in 1907 the country found itself with large stocks, and a year of very light production, but with prices sustained by a common purpose among sellers, was needed for liquidation. In 1909 occurred a great wave of buying and the country restocked itself in the second half of that year and the fore part of the next, liquidating in turn thereafter. In 1912 the buying movement was repeated, though with less enthusiasm, the stocking up process continuing into 1913. At the beginning of 1914 the liquidation in stocks was not entirely completed, though probably nearly so. The trade was due, apparently, for an upward swing had not special conditions intervened. The first was the unwillingness or inability of the railroads to make their usual purchases, insisting that they needed an advance in freight rates to enable them to buy, and month by month during the first seven of the year the market waited for "the rate decision." Not only did the railroads not buy, but other buyers felt there was no occasion to purchase when the railroads were not figuring in the situation. The long expected rate decision, favorable by less than one-half the demands made, was announced on August 1 and fell absolutely flat, for the world was then experiencing the greatest shock in its history. The war then prostrated the steel industry afresh.

By the ordinary rhythm an important revival in the steel trade is months overdue, and the barriers to at least a moderate recovery are removed. By the recent reopening of the freight rate case the railroads are given almost all they originally demanded. The new banking and currency system makes it that financial troubles are largely past. The history of wars is that their worst effects in trade disruption are felt at the start, and the influence of the present war should now be decreasing. That humanity must pay a tremendous bill for this war is beyond question, but the payment will be made over a long period of years, not while the war is in progress.

As a matter of fact the steel trade has already started to experience at least a minor recovery. Beginning with a change in sentiment early in November the movement worked into a stage of heavier buying in December and at the opening of the new year the trend of prices in some commodities at least is distinctly upward.

Readers' Views and Comments

Electro-Analysis of Nickel

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I notice in your November issue an abstract of an American Electrochemical Society paper by Dr. W. Judson Marsh on the electro-analysis of nickel. The methods described have been in use at this laboratory for two years and found to give excellent results. The application of the base metal gauze was described in a paper from this laboratory published in *Metallurgical & Chemical Engineering*, February, 1914. We used a 100-mesh brass gauze, for the reason that a finer mesh can be obtained in brass gauze than in copper. This gave successful results in cases of zinc, nickel, copper, without any rotation. Currents of three and four amperes were employed at first and were cut at the end of the electrolysis to 1 to ¾ ampere.

D. F. CALHANE.

Worcester Polytechnic Institute, Worcester, Mass.

The Action of Fluorspar on Basic Open-Hearth Slags

*To the Editor of Metallurgical & Chemical Engineering.*

SIR:—Any one familiar with basic open-hearth work knows that fluorspar CaF_2 is a very efficient agent in making the basic slag more fluid. Different theories have been advanced as to what reactions take place to give the above result, but none have appeared very satisfactory.

With fluorspar we add calcium which, as the oxide would give us a more basic slag, hence one more thick. We also add fluorine which we would expect to unite with silicon and pass off as a gas silicon fluoride. This removal of silicon would also made the slag more basic, hence thicker. However, we know that the slag is made thin to a very great extent when small percentages of fluorspar are added. The amount of fluorspar necessary being very small, the actual addition of a little calcium and removal of a little silicon would really give no apparent results.

The remarkable fluidity conferred by a small amount of fluorspar being added to a molten slag has suggested to me that the reaction may be a catalytic one; i.e. the fluorspar may be only an agent.

Reactions which I believe may account for the thinning of a basic slag are shown in the following two simple equations, although no doubt more complex reactions do take place.

Silica reacts with fluorspar to yield silicon fluoride and calcium silicate

$$3SiO_2 + 2CaF_2 = SiF_4 + 2CaSiO_3 \qquad (1)$$
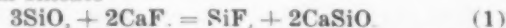
Lime reacts with silicon fluoride to yield fluorspar and calcium silicate.

$$3CaO + SiF_4 = 2CaF_2 + CaSiO_3 \qquad (2)$$
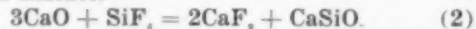
In equation No. 1 the fluorspar reacts with the silica in the slag, giving us silicon fluoride (a gas) and calcium silicate, a fusible slag. Part of the silicon fluoride will escape but a greater part will react with the lime, giving us our fluorspar again and more calcium silicate, the fusible slag. This newly formed fluorspar will react with more silica as in equation No. 1 and the circle is repeated until all the silicon, fluoride gas has escaped. In each reaction some silicate of calcium is formed which is a slag with a low melting point, and the fluorspar has only been an agent to unite the silica and lime, either of which alone is fused with difficulty.

W. S. HAMILTON.

American Steel Foundries,
Granite City, Ill.

Is There a Complex-Ore Problem?

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I have been too busy to reply sooner to Mr. Ionides' letter in your November issue, while this letter has also been delayed by the burning of bridges on the Nacozari Railroad.

I did not assume that the ore mentioned by Mr. Ionides was mined at Broken Hill, Australia. I cannot see what grounds he has for making that assertion. I merely stated that its zinc, lead and silver contents were about the same as that of the ore now being mined at Broken Hill. Even if this ore contains (as he says) a large percentage of pyrite (which the Broken Hill ore does not), I cannot see why that should "render it wholly unadapted to ordinary mechanical concentration." Is it not possible to do as was done at Broken Hill before the flotation process was introduced (as mentioned in a previous letter of mine)? That is to say, could not the lead and some of the silver be saved and the tailings stacked pending discovery of a suitable process? Would not that be better than selling the ore to a smelter and not only losing the zinc but paying a penalty on it?

I thank Mr. Ionides for his offer to put me in direct communication with the owner of this property and gladly avail myself of his offer.

Regarding the extraction at the Broken Hill South Mine during the latter half of 1913, I agree, after studying the figures supplied by Mr. Ionides from the *Australian Mining Standard* (which I had not previously seen), that, as the metal contents of this zinc *tailing* are not in a marketable form, they should not have been included in reckoning up the total extraction. The correct way would be to include the percentage of original contents for ore as contained in the zinc *concentrate* produced by the Amalgamated Zinc Company from the zinc tailing sold to them by the Broken Hill South Co., plus the percentage recovered in the concentrate produced from the slime by the new slime concentrating plant, which is a modification of the Minerals Separation process. I still maintain that a high extraction is obtained at Broken Hill from ore containing silver, lead and zinc—higher probably than at any other mining center—and that it is improving every year.

Mr. Ionides has a good deal to say about "commercial saving" and, of course, I agree that it is the basis of successful mining, but I understood the subject of our argument was mill extraction. The fact that the Broken Hill South Co. sells its zinc tailing to the Amalgamated Zinc Co. and only received about 5 per cent of its gross value in return in no way disproves my statement. If Mr. Ionides will study the figures of the Zinc Corporation, Sulphide Corporation, and Broken Hill Proprietary Co., which themselves treat the zinc tailing produced in their lead concentrating mills, he will see that the "commercial saving" of the zinc is much greater than 5 per cent.

Regarding the question of making a high grade or marketable concentrate from lead or copper slime, this is being done at Broken Hill (with lead slime) by flotation processes with which I am acquainted, and also I understand in Missouri, and I know of a place not 1000 miles from here (to quote one instance only) where they are making a concentrate containing 23 per cent copper from slime containing only 1.5 per cent copper. One of the flotation processes is used. Most of the copper is in the form of chalcopyrite. On a purely chalcocite slime it is possible to make a much higher-grade concentrate.

I have just come across the following figures relating to the operations of the Zinc Corporation at Broken Hill during 1913: "The zinc concentrator treated 350,120 tons of tailing assaying 14.16 per cent zinc, 5.95 oz. silver and 5.7 per cent lead, for a yield of 102,850 tons of flotation concentrate, assaying 44.2 per cent zinc, 12.1 oz. silver and 12.5 per cent lead. The re-treatment of this product by tabling and the Horwood process combined yielded:

	Zinc, %	Silver, %	Lead, %
81,820 tons zinc concentrate assaying	47.1	10.5	7.7
3,082 tons Horwood zinc concentrate assaying	47.3	15.3	9.5
12,623 tons lead concentrate assaying	15.4	31.8	55.4
1,498 tons Horwood lead concentrate assaying	18.8	35.3	32.9
3,442 tons zinc slime for re-treatment	36.7	24.5	16.2

"The sterling value of these products (except the last) was 72 shillings and eight pence per ton of reflotation concentrate, the enhancement, as the result of re-treatment, being £106,985. As the cost of retreatment amounted to £25,035, the profit was £81,950.

"The cost of treatment of tailings in the zinc concentrator (including regrinding) averaged 10 shillings and 2 pence per ton (say $2.44), of which 18 cents per ton represents the cost of operating the Horwood plant."

The following extract from the *Barrier Miner*, published at Broken Hill, may be of interest:

"Tests made on Tasmanian ores show that 85 to 90 per cent of the zinc can be recovered as a high-grade zinc concentrate, assaying 57 per cent zinc, while the same percentage of the lead contents can be recovered in a separate product along with the iron contents of the ore (in a form which makes the material practically self-fluxing), accompanied by also 75 to 80 per cent of the total silver contents of the ore and about 90 per cent of the gold contents."

Do any of your readers know of any place in America where anything approaching this is being done?

Nacozari, Sonora, Mexico.   W. MOTHERWELL.

Grinding Ore for Cyanidation; A Suggested Modification for All Sliming Practice.

To the Editor of Metallurgical & Chemical Engineering:

SIR:—I wonder why we have not heard more about the system of classification of pulp and solution before tube-milling in the all-sliming plants, as suggested by Mr. Pentland in your October issue. Even for obtaining higher-grade solutions for precipitation from the first thickener previous to final agitation and counter-current washing, if not gaining ultimately higher *indicated* extraction.

The two and three-stage crushing plants present unique means of classifying pulps as Mr. Pentland has outlined, and it seems that cyanide metallurgists are slow to perceive and grasp the opportunity where they are not using the counter-current decantation, and depend on filter displacement. What is true in one case, may be adverse in another, but where a large tonnage of solution is used, as in the decantation system, these points undoubtedly should be investigated as otherwise.

I will cite an instance in Arizona, a plant I operated some three years ago, where radical changes were necessary along these lines.

We were confronted by numerous problems. The main apparatus was well enough arranged, but the pulp flow and solution classification did not prove efficient for actual recovery. The indicated dissolution of gold values was simple enough, but it was necessary to make the system more continuous and deliver less dissolved values to the filter.

The crushed ore and solution as delivered and discharged from a Chilean mill, passed a 16-mesh screen to an Akins classifier, where the sand was separated from the slime (24 per cent), and conveyed direct to the 5/22 tube-mill. The slime and excess solution flowed to the first thickener. The gold values were principally in the sand material, and about 60 per cent of the extraction took place in the tube-mill circuit. Instead of returning the tube discharge (1 to 1) to the Akins, a deep cone was installed to receive this partly reground pulp for returning the unground sand to the tube. The density of this pulp was too thick for proper classification. Therefore, as head room premitted it, a portion of the slime and excess solution was tapped from the end and bottom of the Akins to dilute the cone feed, maintaining an overflow of 2½ to 1 ratio. This finished product passed direct to No. 1 agitator, being of the proper density for agitation, where most of the remaining values went into solution. This pulp, after partial treatment, subsequently passed continuously to No. 1 thickener and the clear overflow carried away 80 per cent of the already dissolved values, or 60 per cent of the original ore values plus assay of ongoing mill solution, to precipitation.

The discharge from No. 1 thickener (sand and slime 1 to 1), bypassed No. 1 agitator to No. 2 agitator. Thus the sand (150 mesh) obtained longer treatment while the slime received one-half the treatment originally planned. After installing these improvements the mill tonnage was materially increased. The extra sand treatment enabled less grinding, and the only reason this change was made in the upper part of the plant was to produce high-grade solution for precipitation from No. 1 thickener.

The plant had only two thickeners, one before agitation and the other following to thicken for filtration.

Our ultimate object in view was to obtain as low a grade of pulp as possible for filtration. The overflow from the No. 2 thickener originally passed to precipitation and then to the head of the mill. This was discontinued and in changing the system, the dilute filtration solution was united with the barren precipitated solution, delivered to No. 2 thickener and discharged under the surface of overflow level, below the inflow of pulp from the agitators. In this manner the solids settled in a more barren solution than otherwise. When the thickener is large enough, the scheme of upward displacement works ideally on tube-mill product, and we gained the desired results of delivering a practically barren pulp to the filter.

To overcome the necessary headroom required, and supplying a thicker flow to the tube-mill, I would suggest it better to use the cone for the first classification, providing a Dorr or Akins classifier will separate fine sand from course economically of pulp with the density of 1.250 finished product; suitable for direct agitation. Further in this arrangement and in some cases I suggest a large thickener cone (with goose neck), for sluffing off part of the first crushing solution from the first classifier dilute overflow. This will result in richer and less solution for precipitation, where much solution is used in the first crushing, and low grade. Likewise the discharge of No. 1 thickener would be slightly richer using the sluffing-off tank, but this solution could pass to No. 2 thickener and perhaps perform its duty to better advantage.

Of course, these additions require more headroom, or returning to the old system of elevating separately the tube-mill discharge in returning to the circuit.

In many cases the first slime produced is the more refractory part of the ore, causing higher cyanide consumption, difficult to settle and filter, often requiring more solution ratio and longer treatment, whereas the difficulty in the sand treatment is overcome by the fine grinding. However, in a direct cyanide plant the sands portion from the first crushing generally assays the higher, or contains the larger percentage of original values, and my experience has been that the greater ex-

traction takes place during the fine grinding and the first eight to twelve hours air agitation of the pulp of more dilute consistency. Where the extraction has been poor in the tube circuit and the chemical consumption high, with an six to eight-hour agitation in a restandardized solution and more dilute pulp, directly after the gold or silver has been cleaned by the grinding process, I find a high percentage of extraction takes place.

The only difficulty experienced with the above procedure was the accumulation of coarse sand in the first agitator, but in our case the extraction was better, since this product received longer treatment. We would run continuously for a number of days, and then partly empty the agitator for a fresh start. In treating 150-mesh sands by agitation where the colloidal or first slime has been removed, a shallow tank with numerous air lifts, such as the Parral, would insure less short-circuiting or concentration of the coarse sand. The material treated in a low tank with numerous lifts has a chance to circulate up and down and around the entire tank before passing out. The Dorr agitator would undoubtedly guarantee less danger of this segregation than would the ordinary Pachuca.

EDSON S. PETTIS.

San Francisco, California.

Tube-Milling Tonnage Calculation and Notes on Tube-Milling.

To the Editor of Metallurgical & Chemical Engineering:

SIR:—I have read with much interest Mr. Noel Cunningham's article on calculating tube-mill tonnage, appearing on page 22 of this issue, and have carefully studied his method of calculation and the equation obtained. Mr. Cunningham has handled the subject in a novel manner, and has presented something in which all operators will be interested. A study of his calculation leads to some interesting speculation on the general subject of tube-milling, relating to current practice in all-slime cyanide practice.

In my opinion Mr. Cunningham's equation is correct for certain ideal conditions which, however, are not attained in practice. The necessary ideal conditions would be that the total tonnage be ground to minus 200-mesh, or, in other words, that the quantity of minus 200-mesh pulp overflowing the classifier be equivalent to the

FIG. 1—SHOWING ACCUMULATION IN TUBE FEED DUE TO INSUFFICIENT NUMBER OF TUBE-MILLS

total battery tonnage. Of course this is not the case, as there is always a percentage of plus 200-mesh material in the classifier overflow.

In order to insure having the classifier overflow all ground to minus 200-mesh, it would be necessary to have sufficient tube-mill capacity to grind all the battery oversize to this mesh, and, as it now seems to me, do this in one passage of the pulp through the tubes. Of course, if this were the case, there would be no need of running the tube-mills in closed circuit with classifiers.

All this leads to some interesting speculations on current tube-mill practice in cyaniding, with particular reference to (1) the conditions most favorable for obtaining the maximum fine grinding in a tube-mill; (2) cumulative effect of returning to a tube-mill a part of its discharge that has not been ground to the desired degree of fineness; and (3) the consequent propriety or impropriety of the "closed circuit." Mr. Pentland has touched on some of these points in his article on tube-milling, published in your December issue, page 750, raising some of the same questions from the viewpoint of correct moisture content of tube-mill pulp.

If a tube-mill is unable to crush the entire oversize from its quota of stamps to minus 200-mesh, with one passage of the pulp through the mill, there will be a return of oversize from the classifier. This, in time, increases the load on the tube which, in turn, produces a diminishing percentage of minus 200-mesh material and an increasing percentage of oversize. If a certain amount of this oversize is allowed to overflow the classifier, equilibrium will be established; but if an attempt is made to hold the classifier oversize at minus 200-mesh, the accumulation in the tube-mill will ultimately reach a point where the machine will do little or no work. I am sure all cyanide operators have had such an experience.

Recently there was published a series of tables on tube-milling, some of which are pertinent to this discussion. One of them, given below, bears on the accumulation of oversize under closed-circuit conditions, and the number of tubes required to perform a certain duty.

TABLE I.

Relation of Feed per Mill to Tonnage of Return Feed

Tube-Mills Operating	Feed per Mill	Tons Dry Sand per Day	
		Total Feed to All Mills	Total Return Feed
5	40	200	50
4	80	320	170
3	200	600	450
2	600	1200	1050

Note.—In each case the total initial feed of concentrator tailings passing to the tube-mills was 150 dry tons per 24 hours.

A study of these figures, which are also plotted as a curve in Fig. 1, shows the accumulation in tube-mill feed due to the increasing quantity returned. When this accumulation begins to reach serious proportions, it naturally shows itself in the screen analysis of the classifier overflow; that is, by an increasing amount of plus 200-mesh material. Many cyanide operators (I have done the same thing in the past) will attempt to adjust this by changing the baffle on the classifier or by diluting the battery pulp, so that only the finest material will overflow the classifier. On second thought, however, it will appear that this merely makes matters worse and allows a greater accumulation before the inevitable equilibrium is again established by the overflow of more plus 200-mesh material from the classifier. When such a condition does arise there is no way of adjusting the classifier to prevent it, and the only solution lies in increasing tube-mill capacity. For this reason I consider any adjustment of the classifier as utterly useless. That machine cannot be made to control a condition that is created in the tube-mill and for which the latter is responsible.

This brings up the matter of closed circuit, for if we
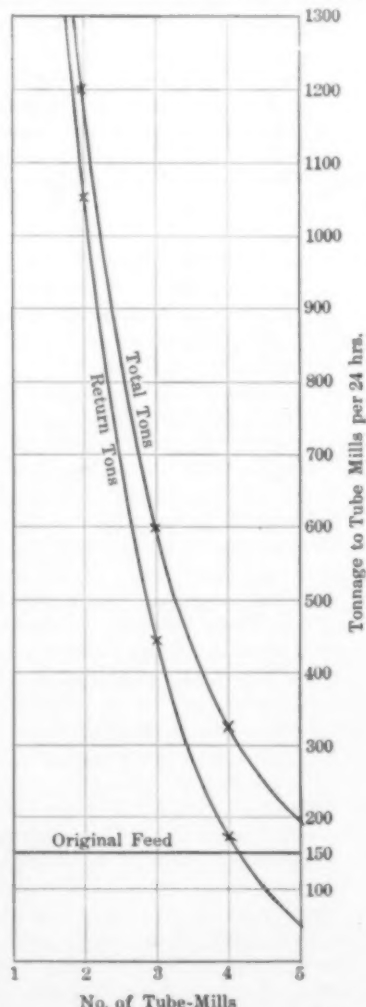
*Eng. & Min. Jnl., Sept. 2, 1914.

increase tube-mill capacity to a point where it will grind the entire oversize as desired, we have then reached a point where there is no need of returning the discharge to the classifier, as the product from the tube-mill will then be practically the same as the classifier overflow.

From the foregoing it can be seen that in a plant

curve in Fig. 2 the data from these tables as relating to the minus 200-mesh pulp produced, except that I have shown actual tons instead of percentages as originally given. This curve shows that, with an increase in the tonnage fed to the tube, the actual *quantity* of material ground to minus 200-mesh increases.
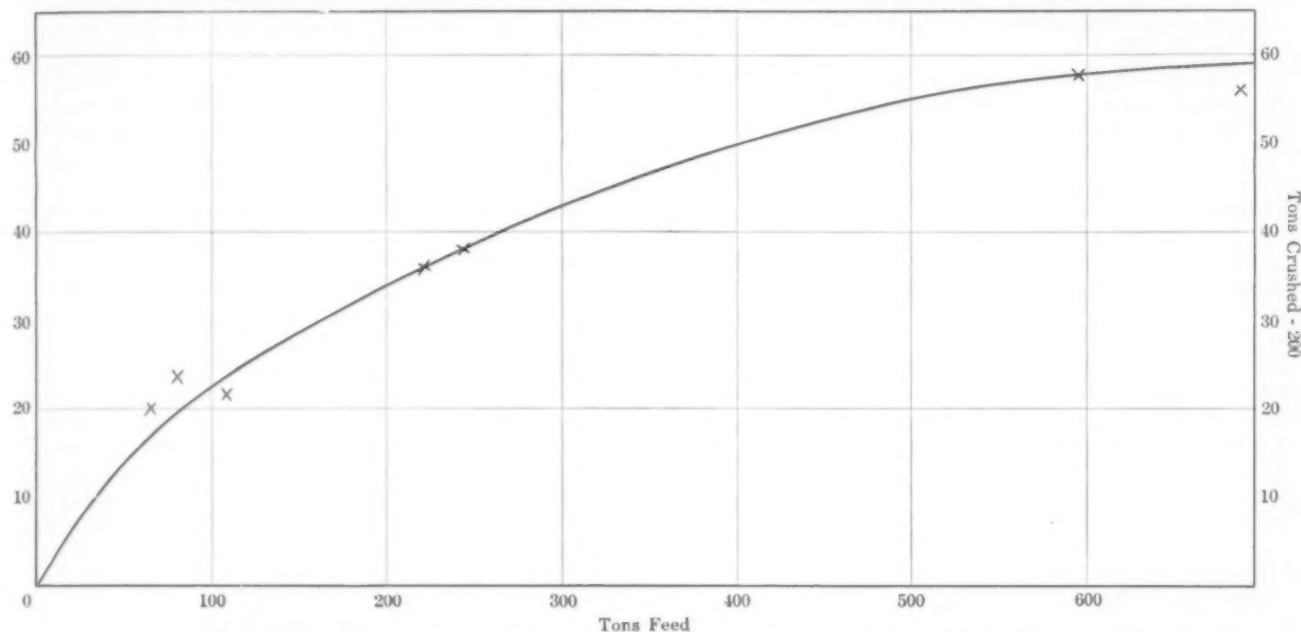
FIG. 2—TONS CRUSHED TO MINUS 200-MESH IN TUBE-MILLS AT VARIOUS RATES OF FEED

containing, say, two tube-mills in parallel, neither of which will handle its tonnage so that the product does not need classifying, it may be possible, by putting the tube-mills in series, to obtain this result. In fact, this was proved to be the case at the Liberty Bell mill, where two tube-mills in series gave a finer product than three tube-mills in parallel in closed circuit.

Other tables appearing in the source already mentioned show the effect on the grinding obtained in tube-mills by varying the tonnage fed. I have plotted as a

But the *percentages* of that product is steadily decreasing, which shows that the feed is increasing faster than it is ground to the desired degree of fineness. In other words, the *per cent* of minus 200-mesh material produced is approaching zero as the feed increases, and will ultimately reach a point where none of that product will be made. The following table gives the figures from which the curve is plotted.

TABLE II

Effect of Varying Tonnage in Tube-Mills

Tons feed 24 hours	67	80	109	217	239	570	693
Per cent minus 200-mesh in discharge	30.03	30.15	20.04	16.56	16.00	10.28	8.09
Tons minus 200-mesh in discharge	20.12	24.10	21.84	35.93	38.24	58.59	56.06

The curve given in Fig. 3, which is derived from the data afforded by the curve in Fig. 2, also has a bearing on the subject of accumulation. Suppose we arbitrarily consider the flow of pulp as intermittent or occurring in cycles, and assume 100 tons of oversize coming from the batteries to the classifier in each cycle. Then in the initial cycle we will deliver 100 tons to the tube-mill, and of this (see Fig. 2) 23 tons is ground to minus 200-mesh, leaving 67 tons of oversize to be added to the next 100 tons of original feed, making a total of 167 tons in the second cycle. By continuing this calculation we get the results plotted in Fig. 3, showing the accumulation in the tube-mill circuit. The only way of preventing this accumulation is to provide sufficient tube-mill capacity to grind the battery oversize in one passage through the tube, whereupon the curve of Fig. 3 would become a horizontal line. That this accumulation does not occur in practice is due to the fact that the classifier acts as an equalizer, maintaining equilibrium by overflow plus 200-mesh material.

The figures given in these tables and curves are not intended to represent general tube-milling practice, and the actual data given will vary widely from similar data on other ores and with other mills, but they illustrate the point I am trying to make.

FIG. 3—SHOWING ACCUMULATION OF PULP IN TUBE-MILL CIRCUIT WITH 100 TONS PER CYCLE OF INITIAL FEED

The general accumulation of ore in the tube-mill circuit is enormous, and is not generally realized by tube-mill operators. As shown in Table I, where two tube-mills were used they were ultimately grinding every twenty-four hours seven times the tonnage of the batteries; and I think I can safely say that this is no exception, as the tonnage usually ground in tube-mills is tremendous as compared with the total tonnage coming from the stamps.

While this discussion has not all been pertinent to Mr. Cunningham's article, it has been suggested by it and by Mr. Pentland's notes on tube-milling for all-slime cyanide practice. The meat of the entire matter resolves itself into the fact that with a certain design of classifier, tube-mill and stamps, working on a certain ore, the degree of fineness of classifier overflow becomes a constant when equilibrium has been established. Absolutely the only way to obtain a larger percentage of minus 200-mesh material in the final product is to increase tube-mill capacity, in which case the closed circuit will not be needed. To put this condition into a formula would require a separate formula for each tube-mill, and a constant due to the ease with which the ore is ground.

JUSTIN H. HAYNES.

Denver, Colo.

The Western Metallurgical Field

Optimism in the Mining and Metallurgical Industry

We hold to optimism because we know that temporary depression is ultimately compensated by activity and prosperity. There are growing evidences that we have passed the period of shock following the declaration of war in Europe, and that we are readjusting ourselves to the new conditions forced upon us. In the West there is a feeling that capital is going to seek investment in mining and metallurgical enterprises, and this sentiment also holds in some quarters of the East, according to reports of engineers who have recently investigated the situation.

At the Phoenix, Ariz., meeting of the American Mining Congress, held last month, Mr. George Otis Smith, director of the United States Geological Survey, expressed the spirit of optimism which is now prevailing. "Europe's war finds its echo in America's industry. Evidence of business betterment is before us on every hand, and the reasons for optimism are many. Foreign orders have started factory operation which at once tends to relieve the stagnation in the steam-coal trade; the steel situation has turned from serious depression to rapid improvement, and the whole mineral industry may soon expect to share in this general business improvement. To-day the financial horizon is so nearly cloudless that the prophets of bad weather have little upon which to base their predictions. Coming down to bottom facts, the United States will profit by the European war only as the nation makes larger and wiser use of its mineral resources."

Heavy Exports of Zinc

Figures compiled by the bureau of foreign and domestic commerce of the Department of Commerce, show that the exports of domestic zinc during September, October and November exceeded the total for the seven-year period ended June 30, 1914. The exports during this period rose to the unprecedented total of 65,504,574 lb., valued $4,443,381, as compared with 1,346,877 lb. valued at $80,756 in the corresponding period of 1913. The year 1897 was the former high-record year in zinc exports, when the total was 35,869,-987 lb. The recent large exports of zinc were for England, Scotland, France, Italy, Denmark, British Africa and Australia. The exportation during the three months above mentioned was about 10 per cent of the domestic production which, in 1912, amounted to 647,814,000 lb.

Mackay School of Mines

The Mackay School of Mines of the University of Nevada has taken steps to increase its usefulness to the state by offering a short course in prospecting. It is expected that attendance on the lectures to be given will have the effect of making prospecting more intelligent and efficient, and consequently contribute to the advancement of mining in Nevada. The course will be offered for four weeks during February, 1915, a nominal fee of $5 being charged. Instruction will be given in excavation of earth and rock, prospecting, mineralogy, geology of mineral deposits, assaying, gas engines, first aid and mining law.

The metallurgical laboratory of the Mackay School of Mines is well equipped for instruction to supplement lectures given in the classroom. The recent addition of a small filter-press to the cyanide equipment makes that department practically complete. It is the policy of this school to use small-size machinery in its laboratory work, rather than standard machines that are too large for frequent use by students. Equipment for metallography and mineralography is now available for the microscopic study of metals and minerals, whereby knowledge is gained that is of use in determining the methods of treatment to which ores are amenable.

Molybdenum in Colorado

The Primos Chemical Co., which already is engaged in mining and treating tungsten and vanadium ores in Colorado, has recently become interested in property at Georgetown, Col., where molybdenum ore carrying some gold and silver has been developed. The company has been engaged in making some surface improvements and underground developments, with the probable intention of erecting a treatment plant of some kind when metallurgical tests have been completed. It is likely that nothing more than some form of concentration will be attempted at the mine, leaving reduction work to be done at an Eastern point.

New Cyanide Mill for Pittsburgh-Dolores Mining Co.

The Pittsburgh-Dolores Mining Company is remodeling the old Rockland mill, situated 27 miles from Yerington, Nev., into a modern cyanide plant. The former mill was erected as a leaching plant, but was not a success and has not been operated for seven years. Preliminary tests on the ore indicated that an extraction of about 95 per cent could be obtained from $12 ore by grinding to 100-mesh and cyaniding. The old, coarse-crushing equipment was therefore supplemented by a 5-ft. x 18-ft. tube-mill, which will grind in closed circuit with a Dorr classifier.

The new mill will have a daily capacity of 60 tons and will adopt continuous decantation. In the old leaching equipment there were five steel tanks, 30 ft. in diameter by 5 ft. in depth. These will be converted into Dorr continuous thickeners. The tanks are shallow, but on account of the large settling area afforded for the tonnage to be treated, and the rapid rate of settlement of the ore, it has been considered safe to commence operations with shallow tanks. Provision has been made, however, for deepening the tanks to 8 or 10 ft. if necessary, by equipping the thickeners with long driving shafts. It may be that 5 ft. will be sufficient depth for such quick-settling material, and that a low-moisture discharge will be induced by the coarse sand packing near the point of discharge.

As the old leaching vats were arranged on the same

level, they will not be changed in the remodeled plant. This will make it impossible to get gravity flow of solution through the continuous decantation system in the preferred manner, and in order to secure thorough mixing of the thickened slime and decanted solution passing to the various thickeners, mixing cones will be installed. The mixture discharged from these cones will be elevated to the thickeners by air-lifts which will be regulated by floats within the cones, rigidly connected with the valves on the air line.

Agitation will be continuous in three Dorr agitators, 22 ft. in diameter and 19 ft. deep. Compressed air will be delivered by a 12-in. x 12-in. compressor run by a 10-hp motor. This will give 150 cu. ft. of air at 20-lb. pressure, which will be used for agitation and air-lifting. The manner of connecting the agitators for continuous work is shown in the sketch, Fig. 1. The adjustable transfer pipe makes it possible to draw off pulp of uniform density and prevent classification within the agitators. A feature of the plant is the small power requirement for the continuous decantation department.
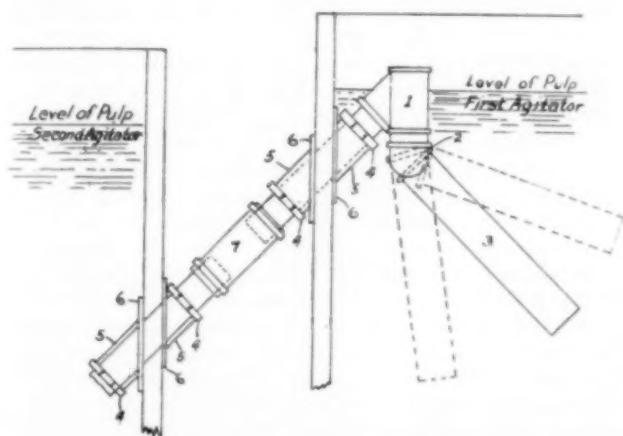

FIG. 1—CONNECTIONS OF DORR AGITATORS IN SERIES

1 Standard C. I. "Y" Bend. 2 Double E II. 3 Adjustable Transfer Pipe. 4 Lock Nuts. 5 C. I. Bevel Hollow Washers to be pressed against gaskets (6) by lock nuts (4). 6 Gaskets. 7 Flexible Rubber-Tube connection.

A 10-hp motor is provided for the operation of three agitators, five thickeners, two solution pumps and five diaphragm pumps. Mr. E. J. Schrader, of Yerington, Nev., is manager for the company.

Normal Conditions Exist in Cobalt

With the resumption of operations at the Buffalo low-grade mill on Dec. 7, mining and milling conditions at Cobalt, Ontario, are about the same as before the declaration of war. The Buffalo company suspended operations four months ago, starting work in the mine after a few weeks, but doing no milling until the date given above. The high-grade mill is still closed, but as it handles concentrates from the low-grade mill, it is likely that it too will be started soon. Weekly shipments from Cobalt continue to increase as the aspect of the silver market improves.

The Cyanide Situation

Speaking before the Mining and Metallurgical Society of America, at a meeting of the New York Section, Mr. Otto Ruhl, of Roessler & Hasslacher, said recently that his firm began the manufacture of potassium cyanide at Perth Amboy, N. J., in 1890. The old method of using potassium ferrocyanide was employed. The first sales were not for gold extraction, but for fumigation of trees. Seven years after beginning production, the first carload was sold at 45 cents per pound.

When the Dingley tariff came into effect in 1897, the rate of duty on cyanide was reduced from 25 per cent to 12½ per cent *ad valorem*, and the domestic production of cyanide was ended until 1902. In that year Roessler & Hasslacher took up the manufacture of sodium cyanide by the synthetic process of Hamilton Y. Castner, an American chemist. "It took fully ten years to reach the high standard of sodium cyanide which we are now producing, equivalent to 128 per cent to 130 per cent potassium cyanide, now universally recognized as the only proper material for electroplating, fumigation and gold extraction purposes." When cyanide was put on the free list by the Wilson tariff act in 1913, the output of the cyanide factory at Perth Amboy was not equal to the growing needs of the country, and it was necessary to import cyanide. At the outbreak of the war it was planned to operate on a larger scale and meet the increased demand. Mr. Ruhl gives the annual consumption of cyanide in the United States as 2000 tons, and of Mexico 5000 tons. According to figures of the United States Geological Survey given in our last issue, the domestic consumption is about 2500 tons per annum. Mr. Ruhl closed with the statement that "under the Dingley tariff of 12½ per cent *ad valorem*, an amount of protection with which we were quite satisfied, we were able at all times to supply the whole American demand. The raw materials we consume are sodium, ammonia and carbon."

Company Reports

Stratton's Independence, Ltd., has issued its annual report for the period ended June 30, 1914. The production of shipping ore, both on company and lessees' account continues to fall off as compared with previous years, and is expected to so continue. The mill treated during the year an average of 11,156 tons per month, the largest tonnage handled to date. The total working cost was $1.3811 per ton, the lowest to date. Deducting the cost of getting ore from the dump, the actual milling cost was $1.27 per ton. Extraction was a round 80 per cent, having increased 1.5 per cent over the previous year. The grade of mill ore fell from $3.076 in the previous fiscal year to $2.879 in the current year.

The mill handled 88,192 tons of dump ore and 45,683 tons of low-grade mine ore. The average gold content was 0.14396 oz. per ton, or a total of 19,273,469 oz. There was recovered in concentrates 7,654.77 oz., or 39.72 per cent; and in cyanide bullion 7764 oz., or 40.28 per cent; total, 80 per cent. The first-grade concentrate averaged 4.358 oz. gold per ton; second grade, 1.848 oz. These products were sold to smelters. The milling cost per ton was divided as follows:

Coarse crushing and sorting	$0.1563
Fine Crushing, concentrating and treating concentrate	0.5040
Cyaniding and special chemicals	0.4672
Miscellaneous expense	0.1425
Total milling cost	$1.2700
Mining dump ore	0.1100
Total cost	$1.3800

The gross profit from treating ore in the mill was $127,760, of which $26,251 was paid to the mine department on the usual schedule of treatment charges for milling low-grade mine ore, leaving a net profit to the mill of $98,509, on the treatment of 133,875 tons of ore.

The third quarterly report of the **Butte & Superior Copper Company** for 1914 shows 100,600 dry tons of ore milled. The average content was 18.58 per cent zinc and 8.64 oz. silver. The quantity of concentrate produced was 60,974,968 lb., containing 33,121,312 lb. metallic zinc, or 54.32 per cent. The average silver con-

tent of concentrate was 24.15 oz. per ton. Zinc recovery averaged 89.14 per cent. Milling cost $2.049 per ton. The estimated net profit for the quarter, calculated on spelter at 5.11 cents, was $499,136. The net spelter return per ton of ore, including estimated value of lead concentrates and zinc residues, was $10.21 as compared with $8.44 for the previous quarter.

The Non-Ferrous Metal Market

Since our last monthly report the prices for metals except tin have advanced, in some cases substantially. Following a brisk domestic demand for copper, European buying strengthened the market. Lead has remained at a low price, slightly in advance of a month ago. Spelter has advanced sharply, due principally to sales to Europe. Tin has declined, following a decline in London and lack of interest among consumers.

Copper.—Sales have been reported at 13 cents, and with renewed selling to Europe the market is firm. Most of the business, however, has been transacted at about 12.75 cents, New York.

Lead.—Business has continued light, but there is a sentiment that foreign countries may soon be in the market for this metal. New York quotations are about 3.80 cents, and St. Louis $3.67\frac{1}{2}$ at $3.72\frac{1}{2}$.

Tin.—This market has declined. Speculators on the London market raised the price for a time, but buyers were disinterested, and the market weakened. December tin in this market is about $32\frac{1}{2}$ cents.

Spelter.—Early in December foreign orders for this metal caused prices to rise sharply. A large business has been done in exports and there is prospect of a continuance of a firm market. New York spelter is quoted at 5.65 cents, and St. Louis at 5.50.

Other Metals.—Business in aluminium has been slow and the volume of sales small. New York quotation is about 19 cents per pound for No. 1 ingots. Antimony prices are weaker in view of weaker demand, and various brands are quoted at from 13 to $16\frac{1}{2}$ cents. The quicksilver market is quiet, with little change in prices. Flasks of 75 lb. are quoted at $52.50.

The Iron and Steel Market

The turn has occurred in the steel trade. The improvement in sentiment that became noticeable early in November has been followed in December by a buying movement which is by no means of spectacular proportions but which nevertheless represents a radical turn from conditions of recent months. In sheets and tin plates the actual shipping orders booked in December have been nearly double those of November. In bars, plates and shapes the increases have averaged 50 per cent or more, while in tubular goods and wire products there have been slight increases.

In most commodities the trend of prices is distinctly upwards. Throughout December the mills quoted 1.05c. on bars, plates and shapes for immediate specification and 1.10c. on contracts involving specification during the first quarter, and at the close of December there was a general withdrawal of the 1.05c. quotation. In wire products there are predictions of an early advance. In the sheet market prices have continued irregular, but have not declined further in the past week or two, and a stiffening in quotations is not improbable in the near future.

The Year's Results

The average level of prices in the finished steel trade in 1914 was the lowest for any year since 1898, when conditions were altogether different. In pig iron prices

have averaged the lowest in recent years, but have not been as low as in 1904.

The production of pig iron in 1914 was about 23,200,000 gross tons, representing a decrease of 25 per cent. from 1913, the banner year. The decrease in steel ingots was greater and in finished steel products still greater, as some stocks of pig iron have been accumulated, and also at some plants there has been a little accumulation of ingots.

The smallness of profits in the year is illustrated by the fact that the United States Steel Corporation's earnings will fall between $70,000,000 and $80,000,000, the only year in its history showing earnings approximately as small being 1904, when the corporation's productive capacity was much smaller than at present.

Pig Iron

The pig iron buying in the Buffalo district late in November was followed by buying of importance in most other districts. The sales by Buffalo furnaces aggregated fully 200,000 tons, and the movement in the Pittsburgh district, somewhat later, involved about 125,000 tons. The Chicago district moved 100,000 tons or more. The movement in southern iron was not in keeping with that in northern, for instead of southern iron leading, as usual, the buying occurred later, and the volume was not large, perhaps 250,000 tons. While the pig iron buying movement as a whole did not by any means reach the proportions of some movements in the past, it represented the greatest concentrated activity for about a year. In some districts there was an apparent yielding in price, but this was simply the replacement of a nominal market by a real market. In the Pittsburgh district there was no change, while at Buffalo and Chicago there were advances after the iron had been sold. The market is now moderately active and prices are quotable as follows: No. 2 foundry, Birmingham, $9.50 to $9.75; delivered Philadelphia, $14.25; f.o.b. furnace, Buffalo, $13; f.o.b. furnace, Chicago, $13; at valley furnaces (95 cents higher delivered Pittsburgh): Bessemer, $13.75; basic, $12.50; No. 2 foundry and malleable, $12.75 to $13; gray forge, $12.50 to $12.75. Ferromanganese is nominally quoted at $68, Baltimore.

Steel

The market for billets and sheet bars is not closely quotable, as most transactions are really in the nature of price adjustments upon long term contracts. There have been offerings for prompt shipment at $18.50 for billets and $19 for sheet bars, at maker's mill, Youngstown, but for delivery over the quarter quotations are about 50c. a ton higher. The Pittsburgh producers are quoting about 50c. a ton higher at mill than the lowest Youngstown sellers.

Finished Steel

Prices quoted below are for contracts over two or three months. In some commodities lower prices for immediate shipment have been ruling, but these are largely withdrawn. Prices quoted are f.o.b. Pittsburgh, unless otherwise stated, but on many products the Chicago and eastern Pennsylvania mills are quoting lower delivered prices in their territories than the equivalent Pittsburgh prices plus freight.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill except Colorado.

Plates, tank quality, 1.10c.

Shapes, 1.10c.

Steel bars and bands, 1.10c.; hoops, 1.25c.

Refined iron bars, 1.20c., Pittsburgh; common iron bars, $1.12\frac{1}{2}$c., Philadelphia; .95c., Chicago.

Sheets, blue annealed, 10 gage, 1.30c.; black, 28 gage, 1.85c.; galvanized, 28 gage, 2.80c.; painted corrugated,

28 gage, 2.05c.; galvanized corrugated, 28 gage, 2.85c.

Tin plate, season price announced Dec. 3, $3.20 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., 81 per cent off list.

Steel boiler tubes, 3½ to 4½ in., 74 per cent off list.

Standard railroad spikes, 1.35c., Pittsburgh; 1.45c., Chicago.

Structural rivets, 1.35c.; boiler rivets, 1.45c.

Cold rolled shafting, 67 per cent off list.

Chain, ⅜ in. proof coil, 3.00c.

"The Little Journal" is the name of a new paper to be published "occasionally" by Arthur D. Little, Inc., chemists, engineers, managers, of Boston, Mass. The catchy name puts at once the reader into good humor, and creates high expectations. These are not disappointed. The contents are worthy of the name Little and what it stands for in American chemistry. There is no smack of amateurishness in this Vol. I, No. 1. Its editorial finish is really remarkable. An article on "raw materials and the war" sketches concisely how the supply of various metals, chemicals, drugs and dyes has been affected by the war. "Dyestuffs," "Radium in America," "Nitrocellulose in War and Peace" are the subjects of further articles, Ernest Solvay and Alfred Nobel the subjects of biographical notes. There are three brief editorials. In the first the cry for an immediate creation of an independent American dyestuff industry is amusingly ridiculed by the proposal to utilize American rainbows. The other two editorials refer to inevitable consequences of the war for the European nations. "European industry will be on a new basis when the war is over," because the overhead charges will be higher, "and costs of production will more nearly approach our own." As to the loss to science due to the war, "the loss to science and the world would have been no less disastrous though unappreciated had Faraday and Curie and Solvay and Helmholtz and Mendeleef fallen on the firing line at twenty-one." We extend to "The Little Journal" our cordial wishes for a long and glorious career.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in September, 1914, was 60. The total quantity of ore milled during that period was 2,242,913 tons. There were 9795 stamps in operation with an average duty of 8.86 tons per 24 hours. Tube mills in commission numbered 292. The yield for the month was 702,170 fine ounces gold.

Bolivian mineral exports, according to American Minister John D. O'Rear, at La Paz, are mainly in the form of high-grade concentrates. There are no smelters in the country. The following table shows in kilos (1 kilo = 2.2046 lb.) the exports of the principal minerals for the last few years:

Minerals	1908 Kilos.	1909 Kilos.
Tin	29,938,282	35,566,415
Silver	156,482	155,360
Copper	2,877,605	3,096,605
Bismuth	160,304	236,762
Wolfram	169,637	152,600
Zinc	1,242	602,000
Lead	5,150	7,000
Antimony	919,735	494,440
Gold	35	42
Total	34,228,472	40,311,224

Exports for the first eight months of 1914, reported in kilos, were: Tin, 26,021,564; silver, 12,624,754; copper, 202,265; bismuth, 163,520; wolfram, 145,780; antimony, 120,770.

"Ironised" Steel Tubes.—From a note in the London *Electrician* of November 20, 1914, we learn that non-corrosive steel tubes will soon be on the market, as the British Mannesmann Tube Co. (Ltd.) have just com-

pleted a plant for ferro-zincing and ironizing tubes, under license from Mr. S. Cowper-Coles. "It is a well-known fact that the purer the iron the less liable it is to pitting and corrosion, chemically pure iron being practically rustless. 'Ferro-zincing' or 'ironizing' turns these facts to account by coating the steel surface with almost pure iron, the only impurity of any significance being hydrogen. The addition of hydrogen is an advantage, for the reason that it makes the iron slightly more electropositive to the underlying steel than it would otherwise be, so that it forms a better protective coating. Another advantage of the coating of electrolytic iron is that the coating is homogeneous, and is not under unequal strain caused by mechanical operations, such as drawing or hammering, and has not been subjected to any heat or mechanical treatment which, of necessity, caused impurities to be absorbed by the metal so treated. It is advantageous for many purposes to coat the electrolytic iron surface with zinc, as a zinc coating with an intermediate layer of pure iron-hydrogen alloy gives a greatly increased life to an ordinary steel tube or plate."

Operating Data on Copper Smelting Furnaces.— The following data, taken from "The Copper Smelting Industries of Canada," a bulletin issued by the Canadian Department of Mines, gives the principal data regarding the operation of the furnaces of the British Columbia Copper Co., Greenwood, B. C. There are three water-jacketed blast furnaces. Originally these furnaces were 48 in. by 240 in. at the tuyeres; the capacity was recently increased about one-third by widening the two end furnaces to 51 in. and lengthening them to 360 in.

Charge, tons per sq. ft. hearth area, 24 hr	6.2
Per cent copper on charge	0.8–1.2
Per cent sulphur on charge	1.6–3.5
Per cent sulphur burnt off	80.0
Per cent coke on charge	12–14
Per cent ash in coke	22–25
Blast, cu. ft. per min	25,000
Blast temperature	Atmospheric
Cooling water for jackets, gal. per hr. 3 furnaces	4,000
Men in 8-hr. shift	20
Matte, per cent of charge	2.0
Matte, per cent of copper	40.0
Matte, sp. gr.	5
Slag, per cent SiO₂	43 –46
Slag, per cent Fe(Mn)O	19 –27
Slag, per cent Ca(Mg)O	21 –28
Slag, per cent Al₂O₃	6 – 9
Slag, per cent Cu	0.2– 0.25
Slag, per cent sp. gr.	3.2

The Nipissing Company, of Cobalt, Canada, has been making no shipments of silver bullion for several weeks. As a consequence the silver shipments from Cobalt have been below the normal. On the 10th of November the shipments from the O'Brien and Dominion Reduction were valued at $48,243.

Nevada's mineral production for 1913 has been valued by the U. S. Geological Survey at $37,842,084, as against $39,111,828 in 1912.

1910 Kilos.	1911 Kilos.	1912 Kilos.	1913 Kilos.
38,548,441	37,073,148	38,614,228	44,594,749
142,977	127,990	123,939	81,289
3,211,987	2,950,023	4,707,188	4,019,635
311,060	414,598	477,748	422,664
210,061	297,272	474,640	282,577
11,897,000	9,795,125	8,961,352	7,367,463
30,485	343,188	1,074,887	1,763,206
524,878	311,715	91,350	....
....	55	78	93
54,876,889	51,316,114	54,525,410	58,531,676

The Boss mine, in the Yellow Pine mining district, Clark county, Nevada, in which platinum has been found, is reported to have been sold for $250,000. Another discovery of platinum ore in the same district is reported from the Aura Amigo mine.

The nitrate industry of Chile is reported seriously affected by world conditions. Small towns have become almost depopulated, commerce is at a stand-

still and financial conditions are unfavorable. The Chilean government has advanced about $1,396,000 to companies that have applied for assistance. Consul D. J. D. Myers of Iquique, Chile, believes, however, that American manufacturers can secure business when normal conditions are resumed.

The **Aurora mill** in Nevada has adopted trays in Dorr thickeners to increase settling capacity.

The **new mill** of the Alaska Gold Mines Co. will present a new departure in gold milling. The ore will be coarsely broken with jaw crushers and gyratories, followed by two series of rolls. This will reduce the ore to a degree of fineness appropriate for rough concentration. The next step will be grinding in pebble mills, followed by the usual methods of concentration and amalgamation. The most radical departure from customary practice is in the abandonment of stamps and the adoption of methods heretofore applied to the porphyry copper ores.

Copper Blast Furnaces and Converters in Canada

There are 29 rectangular water-jacketed copper blast furnaces in Canada at the present time, the majority of which have been in active operation up to the opening of the European war. The total hearth area of these furnaces is 2,580 sq. ft. and the total rated capacity is 15,600 tons in 24 hours. The actual duty varies considerably at the different plants, on account of the differences in ore treated. The following table, taken from Bulletin 209 of the Canadian Department of Mines, prepared by Alfred W. G. Wilson, gives the principal data:

Company	No. of furnaces	Tuyere dimensions	Hearth area in sq. ft.	Ore column, ft.	Approx. rated capacity, short tons
Canadian Copper Co......	5	50x204	70.83	14	400
	1	50x240	83.33	14	550
Mond Nickel Co.........	2	50x240	83.33	12	550
Cons. Min. & Smelt. Co...	1	42x210	61.25	8	350
	1	42x360	105.00	8	650
	1	42x264	77.00	8	460
	1	42x420	122.50	8	700
	1	50x420	145.80	8	875
Granby Cons. Mining & Smelting Co.					
Grand Forks	6	44x266.5	81.41	12	500
	2	48x260	86.67	12	550
Anyox	3	50x360	125.00	12	750
B. C. Copper Co..........	2	51x360	127.50	12	800
	1	51x240	85.00	12	500
Tyee Copper Co.........	1	42x120	35.00	6	200
	1	48x160	53.33	6	300

Five out of the seven copper smelting plants in Canada are equipped with converters. The following tabulation gives the principal data:

Company	Type Basic.	Stands	Shells	Dimensions
Canadian Copper Co.	Pierce - Smith Special	5	5	10' 0"x37' 2"
Mond Nickel Co.....	Basic. Pierce - Smith Standard	2	2	10' 0"x25' 10"
Granby Cons. M. & S. Co.:	Basic. Power & Mining Mchy Co. Acid			
Grand Forks....	shells	3	10	84"x126"
Anyox	Basic. Great Falls type	3	3	12' 0"x5' 9"
B. C. Copper Co....	Acid. Allis-Chalmers	2	5	84"x126"

The **Dome Mines Co.**, Porcupine, Canada, milled the largest tonnage in its history during October, treating 22,500 tons of $4.70 ore.

Ray Consolidated Copper Co. has advised stockholders that the directors have deemed it wise to defer payment of the quarterly dividend which would have been declared payable on December 31, 1914.

A **tin concentrating mill** recently erected at the Leeuwpoort mine in the Transvaal, is said by the *South African Mining Journal* to represent "the last word in tin mining equipment in this country," if not in the world. The plant contains Californian and Nissen stamps, Harz jigs, Richards-Janney classifiers, Buss and Wilfley tables, Isbell vanners and Dorr thickeners—a line of concentrating machinery that will have quite a familiar sound to every American millman.

Gold deposits in the assay office of the United States at Seattle, Wash., during the fiscal year ended June 30, 1913, as reported by the Director of the Mint, amounted to 239,557,528 fine ounces, valued at $5,006,750.25. Of this amount Alaska contributed 173,228,343 fine ounces. The total deposits in this office since its establishment July 15, 1898, to the close of business June 30, 1913, amounted to 12,294,-202.83 fine ounces gold, having a coining value of $211,363,034.76, of which Alaska contributed $106,-248,265.09.

Platinum, palladium and osmiridium are recovered as by-products of refineries in the United States Mints. The following table shows these recoveries for the fiscal year ended June 30, 1913:

	Sponge platinum		Sponge palladium		Osmiridium	
San Francisco ...	205.74	$895.99	....	......	0.35	$1,400
Denver	58.20	2,328.00	10.15	$406.00	......	......
New York	1,403.00	59,712.09	18.10	760.20	...	.....
	1,666.94	$62,936.08	28.25	$1,166.20	0.35	$1,400

Mill Tailings for Road Metal.—In Missouri a considerable amount of road material is obtained from the tailings of the concentrating mills at the zinc mines. This material, which is put on the market as "chats," consists of small angular fragments of chert and limestone. The zinc companies are very glad to get rid of this waste material, which is loaded on the cars by the railroads of the district at a cost of about 6 or 8 cents a ton. It makes more than ordinarily good roads and is widely distributed all through the Middle West. It sells in most places at prices ranging from 50 cents to $1 a ton, but in the neighborhood of the mines it can be had for about 15 cents a ton. It is used for railroad ballast as well as road making. The annual output, according to the United States Geological Survey, amounts to not less than 1,300,000 tons.

The **Nevada Cinnabar Co.**, operating at Ione, Nevada, is reported to have shipped several carloads of flasks of quicksilver to the New York market. The furnace is producing from 20 to 25 flasks of metal daily.

Labor Conditions at Butte.—Labor disturbances at Butte have assumed a new phase: dissension exists within the labor unions, and not between companies and unions. Butte is a copper mining district, and as copper production is affected by the European war, the possibilities of a labor shortage at this time have no terror for the companies. In fact they have taken a radical step in declaring for the open shop in Butte, and hereafter the possession of a union card will not be a prerequisite for holding a job, nor will union representatives be permitted to visit the mines to inspect such cards. Butte has long been a stronghold of unionism and the companies have always dealt with unions, but contending union factions have brought about their own downfall.

Ignition of Gas by Fracture of Small Lamp Bulbs. —In a paper read by Mr. E. A. Hailwood at a recent meeting of the Midland Institute of Mining, Civil and Mechanical Engineers, at Leeds, the author declared that the commonly accepted opinion that it was not possible to ignite gas by the breaking of a small electric lamp bulb was entirely erroneous, and that he had in his experiments produced hundreds of ignitions by that means. He thought that such ignition might possibly be explained by the gas which rushed in to fill the destroyed vacuum being momentarily compressed against the red-hot filament with consequent explosion. He doubted whether the insertion of a fuse would be a remedy. The lamps in question were about 1 to $1\frac{1}{2}$ cp.
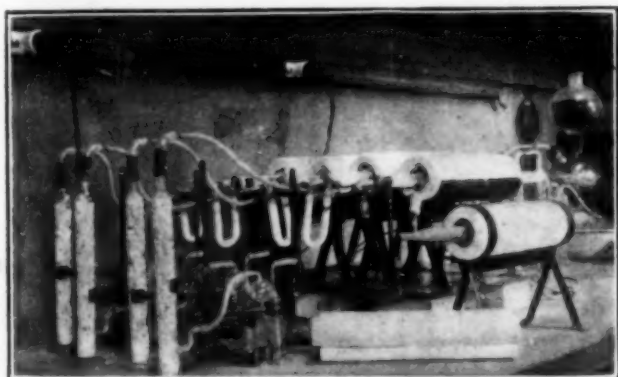
An Electric Muffle Furnace for the Determination of Carbon and Oxygen in Steel and Tungsten Powder

BY CHARLES MORRIS JOHNSON

In 1908, the writer introduced the determination of carbon in iron, steel, etc., by means of the direct ignition with oxygen in an electrically heated furnace. (*Journal*, Am. Chem. Soc., Vol. XXX, No. 5.) Several months ago, he designed a muffle furnace for this purpose which has so many advantages over the original model that he is replacing the twelve furnaces of the old form with this new muffle type in the Park Works laboratory of the Crucible Steel Company of America.

The illustration shows the simplicity of construction. The furnace in the foreground of the picture and containing the tapered clay combustion tube (see Analysis of Special Steels, page 244, for a description of this tube) consists of a split cylindrical muffle of special non-heat conducting composition, of a hoop iron frame, and the nichrome heating element embedded in refractory cement. This heating element is to be seen in the cut, lying on the table in a half muffle. The wire is *not* wrapped around an inner core tube but is covered with the cement and dried on a form. Drying on a form was originated by Mr. I. A. Nicholas for such work.

The four furnaces connected in trains of apparatus show the modification that the author uses for the de-

ELECTRIC MUFFLE FURNACE FOR STEEL LABORATORY

termination of oxygen. If it is desired to cool these furnaces rapidly, the current is shut off and the top half of the muffle is removed. Those desiring further details of the oxygen method should consult pages 74 to 82 of "Special Steels."

The advantages of this muffle furnace construction are: Very low first cost, ease of repair, quick heating and quick cooling. The furnace on a 220-volt direct current will heat from the cold to 1000 deg. C. in from fifteen to twenty minutes! It also presents a cleaner and much brighter appearance than the older style which has a case of black iron. It is easily kept clean and cheerful looking by an occasional dusting, together with the application of some fine-grained sandpaper.

Being of acid-proof material, the muffle is, of course, unaffected by fumes. There are no screws or insulating powder to bother with when the heating element has to be renewed. The later merely is slipped into place.

The following figures give an idea of how cheaply one can build such a furnace:

One split muffle	$2.00
One hoop-iron frame	2.00
Flexible cord and connections	1.50
Heating element	4.50

If the heating element is prepared in the laboratory and the frame support is made by the smith in the works, the above cost can be reduced several dollars.

Pittsburgh, Pa.

Apparatus for the Concentration of Sulphuric Acid

BY WILLIAM MASON

The concentration of sulphuric acid simply means the separation of the acid from water by the process of evaporation. The sulphuric acid as it issues from the chamber system is usually of a specific gravity of 1.560, containing 65.27 per cent of sulphuric acid, and is evaporated until it attains the specific gravity of 1.840 or contains about 96 per cent of sulphuric acid. The weak acid begins to lose water at about 122 deg. Fahr. and boils at 305 deg. Fahr. The strong acid boils at 563 deg. Fahr.; but it is known that this sulphuric acid may be concentrated at a temperature much below its boiling point, namely, at a temperature of about 450 deg. Fahr.

The construction of apparatus for the concentration of sulphuric acid has, at times, had considerable attention. Many forms of apparatus have been invented, and many metals have been used in their construction from brittle glass to the expensive metals of gold and platinum. Of late years apparatus have been built of volcanic lava, but these, it will easily be seen, are very expensive, costing as much at £1,500 ($7,500). It is a fact that although some of these apparatus produced acid much cheaper, requiring less fuel and reducing the cost of labor, they very rarely produced it equal in color to that which was produced by the old-fashioned glass retorts; and, for this reason, the glass retorts are found working in some works to-day.

In the year 1890, Negrier introduced what is known as the capsule system of construction which was further improved upon by Benker. It is an attempt to evaporate fractionally. This form of apparatus has had a very varied career. In the first plant porcelain capsules were used, and it may be that, from the fragile nature of this material, it was not persevered with. However, with the invention of a fused silica material for this purpose, this form of apparatus has again appeared, and plants of the capsule type have been erected in many places, again with varied results. Some

TABLE I.   SPECIFICATION FOR PLANT FOR 4 TONS PER 24 HOURS

	£	s.	d.
Fused silica basins, delivery pipes and coolers	43	8	..
Acid-proof tiles, 1000 acid-proof bricks and cement for same	13	15	..
10,000 ordinary bricks, including 500 arch bricks and concrete	27	10	..
6000 fire bricks of various sizes	16		..
H wrought iron girders and wrought iron stays	14	12	..
Cost of furnace and accessories	7	..	..
6 lead pans, lead vessels for silica coolers, lead vessels for worm type coolers, materials and labor	44	10	..
Iron plates for supporting lead pans	5	5	..
Wood centers for arches, asbestos cord for seating capsules and sundries	3	10	..
Materials and labor for condenser for exit gases, with connections	57	10	..
Cost of labor for erecting plant	30	..	..
TOTAL	265	..	..

TABLE II.   COST OF PRODUCTION OF 1 TON

	s.	d.
Fuel, coals, 2 cwts. at 8 s. 4 d. per ton; fuel, coke breeze, 1 cwt. 2 qr. at 4 s. 6 d. per ton	1	2½
Wages	2	..
General expenses	3	2
	6	4½

TABLE III

	%		%		%
Lead pan No. 1	....	Capsule No. 4	78.84	Capsule No. 13	87.16
" " " 2	.....	" " 5	79.90	" " 14	88.21
" " " 3	65.25	" " 6	80.83	" " 15	89.12
" " " 4	65.25	" " 7	81.47	" " 16	91.08
" " " 5	72.0	" " 8	82.5	" " 17	92.0
" " " 6	74.0	" " 9	83.36	" " 18	93.08
Capsule No. 1	75.25	" " 10	84.42	" " 19	94.37
" " 2	76.0	" " 11	85.34	" " 20	95.25
" " 3	77.66	" " 12	86.23		

firms, after several trials and experiments with furnaces of varied construction have discarded them, preferring the type of apparatus in which the sulphuric acid is concentrated by contact with the furnace gases; but this type of apparatus does not produce an acid as clear as that which is made by the capsule or glass retort systems.

The author, having had several years' practical experience with a capsule plant, gives in the accompanying drawing a description of a plant which gives most satisfactory results. Fig. 1 is a plan, Fig. 2 is a sectional elevation, Fig. 3 a section through *EF*, Fig. 4 a section through *LM*, Fig. 5 a section through *GH*, Fig. 6 a section through *JK*.

Table I (p. 17) is also a specification of the cost of a plant to produce 4 tons of sulphuric acid in twenty-four hours.

The cost of producing 1 ton of sulphuric acid by this plant was as given in Table II.

The working of this plant shows that the concentration of the sulphuric acid proceeds as stated in Table III.

The weak acid recovered by condensing the exit-gases was of a specific gravity 1.240 and was equal to 2.23 per cent of the weight of the acid produced. In the glass retort system the acid in the weak acid was usually equal to about 15.0 per cent of the acid produced.

The great drawback in constructing this type of apparatus has been that of using a forced-draught furnace. Such a furnace gives too high a temperature in the lower part of the plant, which causes much bumping of the capsules. In this way most of the capsules have been broken. An ordinary furnace with careful and regular working of same will produce economically a very colorless acid of satisfactory strength.

Oxford, England.

Quicksilver producers in the United States now have an opportunity to capture the trade with Central and South America and with the Orient from Japan to India, according to a statement by the U. S. Geological Survey. Austrian production, controlled by the government, is cut off from the world market; Italian supplies are considered uncertain; and the Spanish output is controlled in London and probably is not available for foreign trade. Domestic prices for quicksilver had been ranging from $39 to $37.50 per flask of 75 lb. until the war broke out, when they rose rapidly to from $75 to $90 per flask. The price has since receded to about $55. The Nevada Cinnabar Co., operating at Ione, Nev., is reported to have recently commenced production at the rate of sixty flasks per week.

Fig. 3 Section EF

Fig. 4 Section LM

Section JK Fig. 6

Section GH Fig. 5

Scale ⅜ inch to foot

Fig. 2

Fig. 1
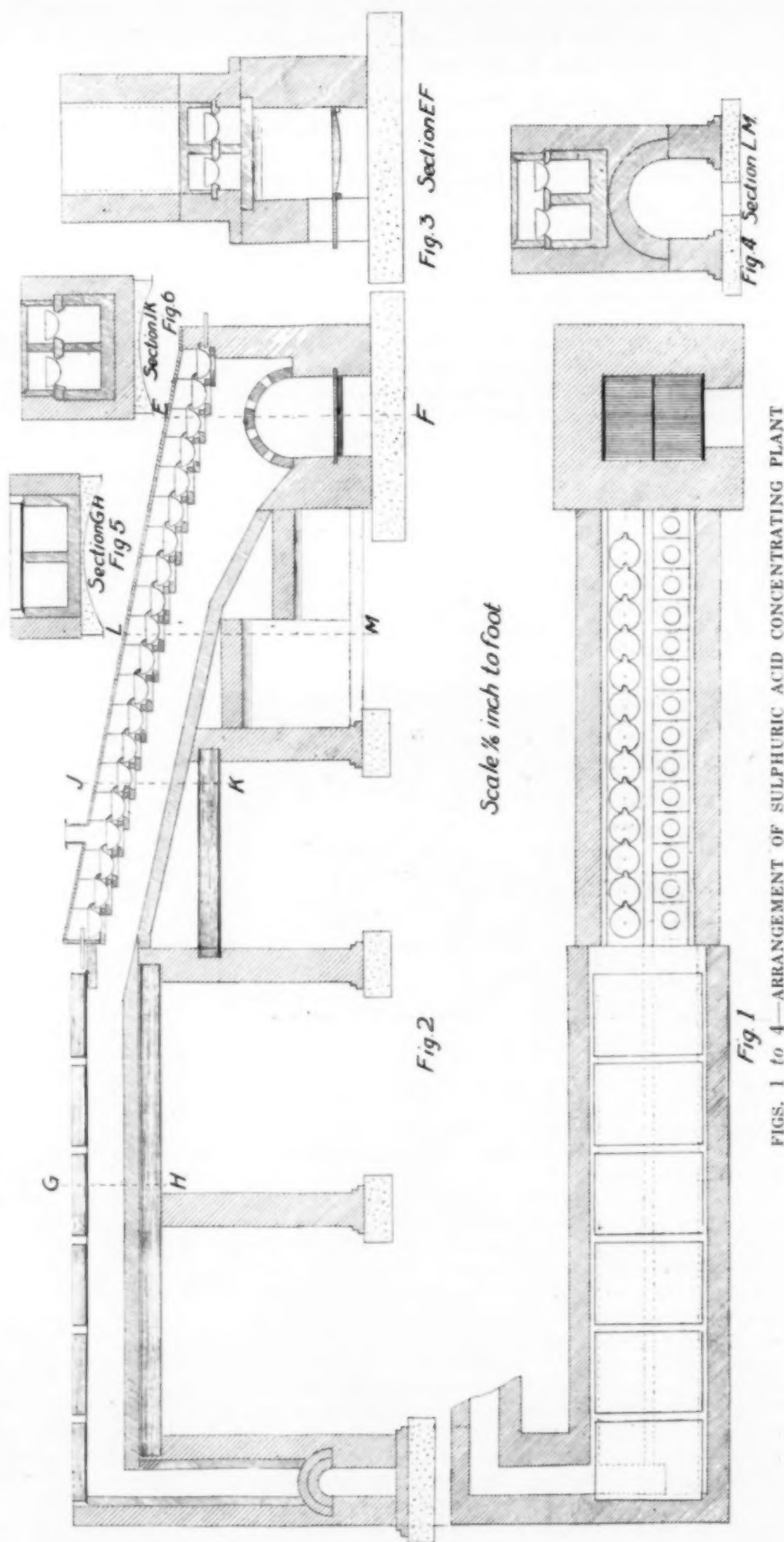
FIGS. 1 to 4—ARRANGEMENT OF SULPHURIC ACID CONCENTRATING PLANT

Refractometry

BY G. A. SHOOK.

III.—Measurement of Refractive Index and Dispersion

As was pointed out in the first article of this series, it is more logical always to express the refraction of any substance in terms of the refractive index for sodium light than in terms of the scale divisions of some particular instrument.

Nevertheless it is manifestly more convenient in certain classes of analysis to express the refraction in terms of an arbitrary number. For example, it is somewhat simpler to designate the refraction of olive oil as 60.2 scale divisions (Butyro Refractometer) rather than in terms of the index for sodium light, namely 1.4660 and since adequate tables are accessible for converting the scale divisions of any arbitrarily graduated instrument into refractive indices—an arbitrary scale is really not objectionable.

Again in the case of an instrument like the Pulfrich refractometer which reads in circular degrees it is necessary to use a table and if the latter is properly constructed the index can very easily be obtained. Other things being equal it is, to be sure, advantageous to have the instrument graduated in refractive indices, but it is not always advantageous to sacrifice accuracy for convenience. On the Zeiss immersion refractometer scale, for example, one scale division corresponds to an increment in the index of about 0.0004 and by means of a vernier a tenth of a scale division can be accurately read, but in the Abbé instrument the fourth decimal place must be estimated. Therefore while the Abbé instrument gives the index directly and while its range is much greater than that of the Zeiss, it is not nearly so accurate.

The Féry instrument, however, has a wide range, but at the same time possesses an accuracy somewhat greater than that of the Abbé.

In the case of a comparatively simple instrument like the Butyro-refractometer, no special directions need be given for its manipulation but with a more complicated instrument like the Pulfrich refractometer it is quite different.

The method of manipulating two of the more complete instruments will now be considered in detail.

Manipulation of the Pulfrich Refractometer

This instrument is used primarily for research work, but it could undoubtedly be adapted for many kinds of commercial analysis.

As a research instrument it possesses many advantages over all the other types of refractometers. It is usually provided with two or three prisms of different refractive powers so that it may be used for practically all ranges. One is also able to measure, not only the index for sodium light but also the index for the C, F, and G' lines. Moreover the mean dispersion $n_F - n_C$, and the partial dispersions $n_D - n_C$, $n_F - n_D$, etc., may be determined. Finally an accuracy is here attainable which is greater than that of any other instrument of its range with the possible exception of the Féry refractometer.

For commercial work it has first of all the advantage of accuracy. Moreover, it is provided with a double cell so that the index of any liquid, say cottonseed oil, may be determined by comparing it with a standard oil. It is only necessary in this case to measure the difference between the two indices, and such a measurement can be made with greater precision than is possible in the measurement of the index. Moreover, since the variation of temperature will be practically the same for the standard and for the unknown oil, the measurement may be made at any temperature whatever.

The oléoréfractomètre of Amagat and Jean utilizes the same principle. This is an excellent instrument, but it is practically unknown in this country.

On the other hand, it is not quite so easy to make a rapid examination of a large number of samples with the Pulfrich instrument as with the Butyro refractometer or Abbé refractometer, for it is more difficult to clean the cell of the Pulfrich refractometer than the face of either the Abbé or the Butyro refractometer double prism. Again, the measurement of the index for the C, F and G' line is carried out by means of a hydrogen tube which is actuated by a small induction coil, and the latter is always a source of trouble.

For industrial use the hydrogen tube should be replaced by a commercial mercury lamp or some similar sort of monochromatic illuminator that can be run on any 110-volt alternating-current circuit.

For a red line a salt of lithium might be volatilized in the flame of a Merker burner just as we produce sodium light from fused sodium chloride. For a green line a thallium salt might be used. The tables furnished with the instrument would not, of course, be applicable if other lines than the C, F and G' were utilized.

There are numerous devices for controlling the temperature of the refractometer prism, but the one now generally sent out with this instrument is perhaps the most satisfactory.

Since the index of an oil is decreased by 0.000365 for each degree rise of temperature, it is essential to maintain the temperature of the cell within a few tenths of a degree.

Adjustment of the Pulfrich Refractometer

To adjust the hydrogen tube, H Fig. 1, fill the cell C
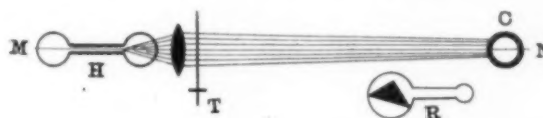
FIG. 1—DIAGRAMMATIC VIEW OF THE PULFRICH REFRACTOMETER

with any liquid (water will do) and turn the reflecting prism R out of the path of the rays from the tube H. By reference to the tables, furnished with the apparatus, for the particular prism, estimate roughly the position of the C line and then turn the telescope to this position so that when the cell is properly illuminated the C line will appear in the field of view.

With the current passing through the tube adjust the latter so as to produce the best illumination. Considerable care may be required to make this adjustment, for if the axis of the capillary tube is not in line with the optical axis of the instrument M N, the brightness of the lines is seriously impaired.

The cross wires in the telescope are always set on the upper edge of the line and not on the lower. By means of a shutter T the light coming from the upper half of the collimating lens may be cut off. By cutting out all of the extraneous light with this shutter the lines are rendered more distinct. If the entire aperture of the lens is exposed, they become ill-defined and an accurate setting is made impossible.

The C line is bright red and with most liquids sharp on the upper edge. The F line is blue-green and it is difficult to distinguish it from the other green lines that lie between it and the C line. The G' line is very faint and difficult to work with. Even the F line cannot be seen in the case of a liquid like butter.

If the tube happens to contain impurities such as mercury, water vapor, etc., other lines will be present

which may obscure the C, F and G' lines or at least confuse the observer as to which is the F or G' line, as the case may be.

The quickest way of identifying the F line is to take the index of water for the F' line, which at room temperature is about 1.338, and determine from the tables the angle at which the telescope should be set so that the cross wires will be just about on this line. By turning the telescope to this position the line may be easily identified.

Before making any measurements it is necessary to make certain that when the telescope is in the position to receive the rays leaving the refractometer prism normally the reading on the circular scale is zero. This normal position is determined by means of an eye-piece of special construction.

A portion of the cross wires W, Fig. 2, in the focal plane of the telescope, is intercepted by a reflecting

FIG. 2—CROSS WIRES OF THE PULFRICH REFRACTOMETER TELESCOPE

prism P. If light is admitted to this prism by placing the apparatus near a well-lighted window or by simply holding a light near the eye-piece (to the right of the observer), an image of that part of the cross wires which is cut out by the prism P will be formed on the opposite side of the field of view as shown by the second diagram.

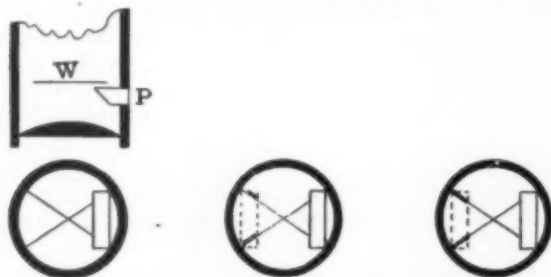This image is due to the light which is transmitted down the telescope and reflected back again by the vertical face of the refractometer prism. Consequently, if the incident beam strikes the prism surface normally it will be reflected normally, and therefore the image of the wires will coincide with the wires themselves as shown in the third diagram of Fig. 2.

The telescope should be rotated until this condition of coincidence obtains and then the reading of the circle should be noted. If it does not read zero, a correction should thereafter be applied.

The support carrying the prism and cell should always be clamped to the standard to which it belongs before making any measurements.
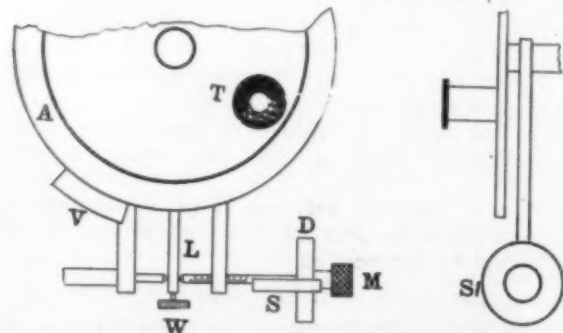
The circle A, Fig. 3, of the instrument reads to min-

FIG. 3—MICROMETER OF THE PULFRICH REFRACTOMETER

utes by means of a verner V, but if a fraction of a minute is desired the micrometer M is used.

When the screw W is tightened, the circle is clamped

rigidly to the lever L, and it can then only be rotated by means of the micrometer M. By means of M the circle, and consequently the telescope, may be turned through six degrees. The drum D is divided into 20 parts and each part represents one minute. The tenth part of a minute can be read directly from the drum and this is as close as one can set the cross wires under the most favorable circumstances.

This range of six degrees is long enough to measure the dispersion of any substance so that the circle need not be read for dispersion measurements after it is once adjusted and clamped by the screw W.

In the tables furnished with the instrument the index for the D line is given for every ten minutes, and the value for each minute must be determined by interpolation. For each of the ten minutes of angle a "correction," so called, is given to be applied to the C, F and G' lines. The method of obtaining data for the determination of the index for any line may be best illustrated by means of an example.

With water in the cell the angle for the D line, as read from the circle, was 67° 28' and the micrometer read 2° 40'. For the C line the micrometer read 1° 49', and for the F line 5° 13'. The angular difference for the D and C lines is therefore

$$2° \ 40' - 1° \ 49' = 51'$$

and consequently the angle corresponding to the C line is

$$67° \ 28' - 51' = 66° \ 37'.$$

In like manner the angular difference for the F and D lines is

$$5° \ 13' - 2° \ 40' = 2° \ 33'$$

and the angle for the F line is

$$67° \ 28' + 2° \ 33' = 70° \ 01'.$$

From the table, for the particular prism, the index for the D line corresponding to an angle of insidence equal to 67° 28' is 1.33328.

For the angle 66° 37' the index of refraction for the D line is, from the table, 1.33728, and the correction for the C line is — 596, whence the index for the C line is

$$1.33728 - 596 = 1.33132.$$

The n_d corresponding to the angle 70° 1' is 1.32196 and the correction for the F line is + 1517, whence the index for the F line is 1.33713.

We finally have the following results:

$$n_c = 1.33132$$
$$n_d = 1.33328$$
$$n_f = 1.33713$$

and the mean dispersion is

$$n_f - n_c = 0.00581$$

Manifestly this computation is far too laborious to render the method applicable industrially. If a large number of observations are to be made it is decidedly advantageous to make out a table giving the index corresponding to the C, D and F lines for each degree. This table need include only values for the particular range in which the experimenter is working.

The writer, for example, made out such a table extending from 42° to 48°, and this range corresponds to a range of refractive indices from $n_d = 1.4417$ to $n_d = 1.4775$ for prism Ib. This table is suitable for most of the edible oils. A portion of it is given in Table I.

TABLE 1—REFRACTIVE INDICES FOR PRISM IB

Angle	D	C	F
42° 0'	1.4775	1.4721	1.4911
1	74	20	10
2	73	19	09
3	72	18	08
4	71	17	07
5	70	16	06
47° 57'	1.4420	1.4365	1.4559
58	19	64	58
59	18	63	57
60	17	62	56

Furthermore, since it is easier to read the micrometer than the vernier, of the circle, the former should always be used and it should be set so that some number on the micrometer corresponds to a particular number on the circle. The necessity for making a subtraction each time is thus obviated.

For the above table the circle was set at 45° and held there firmly. The screw W was then released and the micrometer was set at 2°. It is easy enough to remember that 2° on the micrometer scale S corresponds to 45° on the circle and that 1° corresponds to 44°, etc.

The angle can thus be easily read to one-tenth of a minute, if justifiable, and by means of such a table as is shown above the index for either the D, C or F line may be found directly.

While the index for sodium changes markedly with the temperature, the mean dispersion $n_F - n_C$ changes only slightly, indeed less than one part in the fourth decimal place for a temperature change of about 10° C. Therefore if the mean dispersion were measured at room temperatures a few degrees of fluctuation of the temperature would not affect its value and therefore the temperature would not have to be taken into account.

For some classes of work this constant might be as useful as the index for sodium light. The mean dispersions for a few oils are given in Table II.

TABLE II—MEAN DISPERSION OF EDIBLE OILS (45° C)

Oil	n_d	$n_F - n_C$
Cedar	1.50570	0.01031
Linseed	1.45928	0.01018
Castor	1.47027	0.00904
Cod liver	1.46984	0.00988
Lavender	1.46084	0.00953
Cottonseed	1.46394	0.00953
Hempseed	1.46889	0.00962
Rapeseed	1.46553	0.00933
Sesame	1.46429	0.00932
Olive	1.46040	0.00877
Butter	1.45296	0.00784
"	1.45246	0.00839
"	1.45226	0.00828
Cocoanut	1.44746	0.00739
Margarine	1.44606	0.00832

These values are taken from the recent work of Szalágyi.

The values of the mean dispersion for all liquids of commercial interest have never as yet been accurately determined and therefore can not be given.

With dark colored solutions it is difficult to make an accurate setting on the F (green-blue) line and therefore the mean dispersion in such cases can not be accurately determined unless a stronger light than that emitted by a hydrogen tube is available. With a high-power mercury lamp such a measurement could be easily carried out.

With transparent solutions, however, the mean dispersion can be determined to an accuracy of about two parts in the fifth decimal place.

Failure of the Refractometer to Detect Adulterants

While the refractometer may be successfully used to indicate the purity or the uniformity of a simple product like olive oil or natural butter, it may be easily demonstrated that it is practically useless for detecting the presence of a number of adulterants.

One often finds in reliable books on food analysis a statement to the effect that if the index of refraction (for some standard temperature) of a certain product, say, butter, does not exceed a particular value, the sample may be pronounced pure and chemical analysis may be dispensed with. Let us consider the following cases:

The limits of the index of refraction for natural butter at 25° C., according to Wollny, are 1.4590 to 1.4620. For most oils the index decreases by about 0.00037 for each degree rise in temperature so that for 35° C, the corresponding limits are approximately 1.4553 to 1.4583. Woolny suggests that, to remove all chances of adul-

terated butter escaping detection, the upper limit should be still lower at 35° C., about 1.4573.

A given sample of creamery butter examined by the writer gave an angular reading of 45° 35′ and the index for this angle, from his table, was found to be 1.4562, which is clearly within the limits of pure butter.

A sample of oleomargarine gave a reading of 1.4590, which is a little low, but not low enough, of course, to pass for butter.

For a cocoanut oil a value of 1.4498 was found for the index.

A mixture consisting of 2 cc. of oleomargarine and 1 cc. of cocoanut oil, upon examination gave a value of 1.4560 for the index, which is also within the limits of pure butter. Moreover, this mixture since its refraction is practically identical with the refraction of pure butter, could be used to adulterate butter to any degree whatever.

A second mixture consisting of 1 cc. of the first mixture (oleomargarine and cocoanut oil) and 1 cc. of butter gave for n_D a value of 1.4562. To be sure, there are other methods for determining the adulterants of butter, but it is evident from these examples that mixtures can be compounded which will render the refractometer useless.

Again, if the butter were low, a considerable amount of oleomargarine could be added before it reached the upper limit or if its index were high it might be adulterated with cocoanut oil.

Consider another example: A sample of olive oil gave a value of 1.4628 for n_d. At a temperature of 25° C. the limits for olive oil are 1.4660 to 1.4680 and for 35° C. about 1.4623 to 1.4643, so that this oil was within the limits, but had a rather low index. It was adulterated by adding an equal volume of cottonseed oil with the result that the index was increased to 1.4638, which is still within the limits.

The mean dispersion for this mixture was found to be 0.0090, but this difference in disperson is hardly great enough to pronounce the sample impure. If we had instruments for detecting smaller differences in the mean dispersions we might make use of this constant for detecting adulterants. However, it would not be difficult to produce a mixture which would not only possess the desired index but also at the same time any desired mean dispersion.

A second mixture consisting of 2 cc. of cottonseed oil and 1 cc. of cocoanut oil give for n_d a value of 1.4612 which is just below the lower limit. A smaller amount of cocoanut oil would bring the mixture within the limit. The mean dispersion in this case was 0.0086.

For a mixture of 2 cc. of lard oil and 1 cc. of cottonseed oil the index was found to be 1.4638. Varying amounts of this mixture could, of course, be added to olive oil as desired.

It is thus seen from the above examples that while an abnormally high or low refraction may be a sufficient characteristic of an adulterated product, it is most certainly not a necessary characteristic.

As far as the refractometer alone is concerned the unscrupulous manufacturer may easily deceive the analyst.

This is, however, only one of the many uses for the refractometer so that its value in chemical analysis must not be depreciated.

Manipulation of the Abbé Refractometer

The initial adjustment of the Abbé refractometer is now usually made in the following manner:

The telescope is rotated about the horizontal axis of the instrument until the plane of the upper prism is nearly horizontal, as shown in Fig. 4. A rectangular glass plate optically plane on one face and one end is

furnished with the instrument and its index for sodium light is 1.5176. A drop of monobromonaphthalene (n_d = 1.658) is placed on the prism face and the test plate is then placed on the prism. If the plate is held in place in any manner the instrument need not be rotated into this rather awkward position for making an observation.

It is necessary that the liquid between the two surfaces have a greater index of refraction than the plate, but the value of the index of the liquid is not used in any computation. The prism, by means of the alidade, many now be slightly rotated until the intersection of the cross wires coincides with the boundary or critical line. If the critical line is not colorless rotate the com-
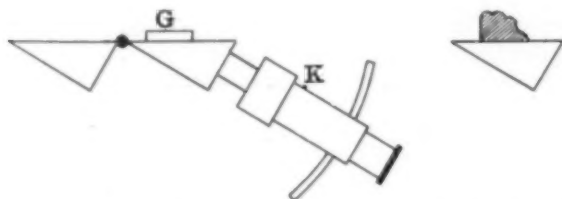

FIG. 4—EXAMINATION OF SOLIDS BY ABBE REFRACTOMETER

pensator until all color disappears. If the instrument now reads 1.5176 no further adjustment is necessary and it will read correctly throughout its entire scale.

If, however, it does not indicate this value it can be made to do so by slightly shifting the cross wires. This is done by inserting a watch-key at K, Fig. 4, and turning the key until the critical line coincides with the intersection of the cross wires when the instrument is set at 1.5176.

Any transparent solid body, such as a piece of glass or quartz may be examined in a similar manner if it has two polished surfaces at right angles to each other as illustrated by the second diagram of Fig. 4.

The lower prism may be so tilted that the light reflected from the bright metal surface will enter the polished surface of the specimen normally. It is essential that the two polished surfaces intersect in a sharp edge since it is necessary that the light strikes the under surface of the specimen at grazing incidence.

From the reading of the compensator the dispersion can be estimated by means of a special table. This instrument, however, is not sensitive enough to detect small differences in the mean dispersion.

In Table III the readings of the compensator are given which were obtained for cottonseed, olive, and cocoanut oil:

TABLE III—READING OF THE ABBÉ COMPENSATOR

Oil	Scale Reading
Cottonseed	39.5
Olive	39.7
Cocoanut	40.1

The reading of the compensator for practically any liquid will fall somewhere between 39 and 41, and since the tenth part of a scale division must be estimated it is readily seen that such an instrument cannot be used for accurately determining the mean dispersion unless a very large number of observations are made. For such measurements an instrument of the Pulfrich type should be used.

University of Michigan,
Ann Arbor, Michigan.

The Santa Gertrudis Co., Ltd., reports that milling operations which were resumed on July 6, 1914, are continuing without interruption. Crushing is limited to about 85 per cent of the capacity, and it is not intended to increase this production until Mexican conditions become generally more settled and until a more certain supply of cyanide can be arranged.

Tube-Mill Tonnage Calculation

BY NOEL CUNNINGHAM

It is often difficult to determine the tonnage actually being handled by tube-mills working in closed circuit with classifiers. Where either tube-mill feed or discharge can be deflected and weighed for short periods it is still a quite inexact determination, as an accurate moisture sample is essential; and where a portion of the pulp is cut out of the flow and weighed, if the amount is sufficient to accurately determine the weight of total flow, it is next to impossible to get a close sample for moisture. In any case, only by averaging a number of weighings and moisture determinations can data of any value be obtained, and as it is an awkward, sloppy test it is not run often enough to be of real value.

The following method is, I believe, original with myself, and allows a close determination of tonnage from four screen tests which are often a part of either daily or periodic routine. The four samples required for these screen tests are: (a) Battery discharge, (b) tube-mill feed, (c) tube-mill discharge, and (d) classifier overflow.

The object of the calculation is to determine the ratio of dry tons tube-milled to dry battery tonnage. The calculation is based upon the fact that the minus 200-mesh material coming to the classifier is equal to the minus 200-mesh which leaves the classifier.

Let a = per cent minus 200-mesh in the battery discharge

     b = per cent minus 200-mesh in the tube-mill feed

     c = per cent minus 200-mesh in the tube-mill discharge

     d = per cent minus 200-mesh in the classifier overflow

     B = dry battery tonnage

     T = dry tons tube-milled.

Now the minus 200-mesh material coming to the classifier is the sum of that in the battery discharge (aB) plus that in the tube-mill discharge (cT); while the minus 200-mesh material leaving the classifier is the sum of that in the tube-mill feed (bT) plus that in the classifier overflow (dB), hence:

$$aB + cT = bT + dB$$

$$\text{and} \quad \frac{T}{B} = \frac{d-a}{c-b}$$

= ratio dry tons tube-milled to dry battery tonnage.

Thus, knowing the dry tons passing through the battery daily, the dry tons actually tube-milled daily can be readily calculated from the routine screen tests.

It is interesting to study the limits of this ratio in practice. I should say in a general way that the minus 200-mesh in modern fine-grinding plants for the four screen tests entering into the above calculation would lie between the following limits:

	Per cent minus 200-mesh	
	Minimum	Maximum
Battery discharge	10	30
Tube-mill feed	2	8
Tube-mill discharge	35	60
Classifier overflow	60	90

The lowest value of ($d - a$) within these limits would be 30 and the largest value of ($c - b$) would be 58, hence within the above limits, tons tube-milled could never be less than half of battery tonnage. In the same way the highest value of ($d - a$) within the limits above would be 80 and the lowest value of ($c - b$) 27, or the maximum tonnage tube-milled within the above limits could not be over three times battery tonnage. Generalizing I should say that for mills where tonnage is being pushed, this ratio would be about 1.75 and never under 1.

New York City.

Comparisons of Electric Resistivities at High Temperatures

BY CARL HERING

Our knowledge of the electric resistivities of conductors at the higher temperatures, hence including those of molten metals, heated refractories, etc., is somewhat meager, although some important contributions have been made recently. In the design of those electric furnaces which are based on high-temperature resistance, these data are of considerable importance, both the absolute values of the resistivities and their comparisons. A comparative study of such resistivities might also lead to a discovery of some useful general physical law.

What meager data exists are greatly scattered in the literature; such values are sometimes given as conductivities, sometimes as resistivities, and often in entirely different units; sometimes the units are omitted entirely, this rendering the results nearly valueless. In some cases the mere resistance of a piece is given, without the necessary dimensions which would enable the resistivity (specific resistance) to be determined. In some cases true resistivities are given as "resistances," as in the French literature, for instance. Some of the data are given in curves, each with entirely different scales (for good reasons), in some cases different parts of one curve are even given in entirely different scales, even relatively different. The temperature coefficients are sometimes given in entirely different forms which in some cases are unintelligible; these coefficients and the abrupt changes during melting and vaporization are of importance as they cause some of the values to change relatively quite greatly at the higher temperatures.

A comparison of the different resistance materials, their ranges of temperature and their rates of change, both relative and absolute, therefore becomes tedious. Tabulated figures, even when well arranged, do not give the clear and direct mental picture that curves drawn to the same scale do; hence to facilitate such comparisons and to make their relative values more directly apparent, the writer has compiled what data he could find and has combined most of them in the uniform sets of curves given below, charts 1 to 5, in which all in each set have been reduced to the same scales. For more accurate values the original data should be consulted, though this is sometimes very crude, hence only roughly approximate.

When thus directly compared quantitatively, such curves show some interesting results. Moreover, as the relative values of the different materials often change very decidedly with increasing temperatures, curves are the only way to represent them directly and clearly; no tables, no matter how well arranged, could present the results so directly.

It is believed that this is the first attempt to make a compilation of this kind, and it is suggested that these charts be republished from time to time by this journal with amplifications, new data, and corrections from those who can contribute them.

The temperature scales are the same in all. Owing to the extremely wide range of resistivities, about 400,000,000, it is, of course, impossible to have them all on one chart. The scale of ordinates in each chart has been made twenty time that of the preceding one, except in the case of chart 3, in which the increase is 2500 times, there being few if any materials in that range, namely, between the metals which increase with temperature and the non-metallic materials which decrease; in general between 0.005 to 0.5 ohm. Solid graphite and carbon are more of the order of magnitude of the metals, hence are with the low-resistance materials, while silicon and powdered or granular graphite and carbon are nearer to the high-resistance group.

Some of the curves are duplicated on two successive charts so as to facilitate comparisons; but none could be carried over from chart 2 to 3 on account of the very wide range between them. The scale of chart 5 is just 1,000,000 times that of chart 1.

The observed values are shown in full lines; the dotted lines are exterpolated and should therefore be used with some reserve. It is believed that for pure metals at least all electrical resistance vanishes at absolute zero of temperature. Furthermore, recent determinations by several physicists indicate that the resistivities of some metals at least seem to increase linearly above their melting points. If these two laws, on which most of the exterpolations have here been based, are correct, the exterpolated values are probably not far wrong; and until actual determinations are made they will at least serve as probable approximations; moreover, until then they are the only data we have, and are therefore probably better than none. The writer, therefore, feels justified to make them here, even though they are not established data.

The termination of a curve with a small circle means that this is the maximum temperature at which these materials can be used, according to their makers. In the case of most of the liquid metals, their boiling points are shown by short vertical dotted lines, indicating a probable abrupt though unknown increase of resistivity; beyond their boiling points they are, of course, no longer available as liquid resistors. As metals usually go through an abrupt change of resistivity at their melting points, these latter are readily noticed on some of the curves. Both melting and boiling points are given numerically in the text in conjunction with the references. The melting points have been taken largely from the tables of the Bureau of Standards and the boiling points largely from the Smithsonian Physical Tables.

The resistivities in the text are here all given in microhm, centimeter cube units, unless otherwise stated. The conversion figures are:

resistivities in inch cube units = resistivities in cm cube units $\times$ 0.393700;

resistivities in cm cube units = resistivities in inch cube units $\times$ 2.54001.

Both co-ordinates of the present curves have been started at zero (the absolute zero, in the case of temperature), so as to facilitate direct comparisons and the finding of any general laws, if they exist.

References to most of the original sources of the data, where in some cases more detailed data may be obtained, are given below. The present writer, however, has supplemented these data with additional matter, deductions and comments, for which he assumes the responsibility.

The scale of Fahrenheit degrees is given at the top of each chart, and the scales for the values for 1-in. cube are given on the right-hand side.

For the temperature coefficient the usually adopted form is here used, namely, a in the formula $R = r (1 + at)$, in which R is the resistivity at $t°$ centigrade, r that at $0°$ C.; sometimes the latter is given at $20°$ C., in which cases 20 should be subtracted from t; but for the higher temperatures here dealt with this correction is of no importance. For the higher temperatures there is sometimes an additional factor $\pm bt^2$ in the parenthesis, but in most cases the values are not known with sufficient accuracy to warrant such refinement, hence this has in most cases been neglected here.

In some cases the curves, representing the changes with temperature, when more accurately drawn, are not quite straight lines; it may be possible that this is due to a change of volume due to expansion, or to a propor-
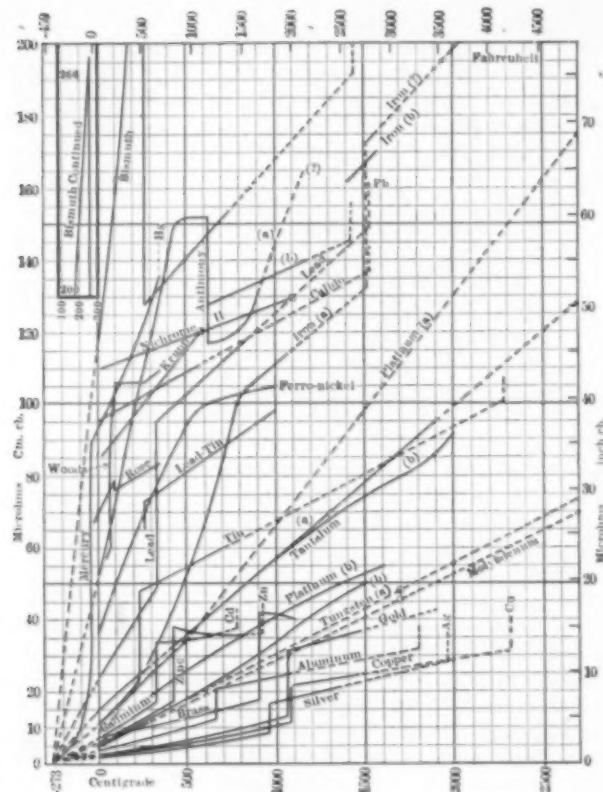
CHART 1

CHART 2

TABLE I

(Values in italics are merely exterpolated)

500°C. 932°F.	Microhms Cm. Cb.	1000°C. 1832°F.	Microhms, Cm. Cb.	1500°C. 2732°F.	Microhms Cm. Cb.
Silver, solid	3.0	Copper, solid	9.42	Silver, fused	*23.*
Copper, solid	5.1	Gold, solid	12.54	Copper, fused	*24.8*
Gold, solid	6.62	Silver, fused	17.01	Aluminum, fused	*29.*
Aluminum, solid	10.	Aluminum, fused	24.	Gold, fused	*37.*
Brass, 2-1, solid	12.5	Molybdenum, solid	*58.5*	Molybdenum, solid	*40.5*
Molybdenum, solid	*16.5*	Tungsten (a), solid	*30.5*	Tungsten, solid	*43.*
Tungsten (a, b), solid	18.	Tungsten (b), solid	33.4	Tungsten (b), solid	50.
Platinum (b), solid	25.3	Platinum (b), solid	40.8	Platinum (b), solid	52.6
Cadmium, fused	34.12	Brass, 2-1, fused	41.	Tantalum, solid (b)	74.
Platinum (a), solid	34.4	Tantalum, solid	57.	Tantalum, solid (a)	78.
Tantalum, solid	36.	Platinum (a), solid	*66.*	Tin, fused	*80.5*
Zinc, fused	36.60	Tin, fused	68.	Platinum (a), solid	*96.*
Iron (a), solid, about	52.	Lead-tin alloy, fused	98.	Iron (a), solid, about	*131.*
Tin, fused	54.62	Ferro, nickel, solid	105.	Calido, solid	*136.*
Lead-tin alloy, fused	81.	Iron (a), solid, about	*111.*	Lead, fused	*148.*
Ferro, nickel, solid	94.	Calido, solid	*122.*	Iron (b), fused	*166.*
Lead, fused	102.85	Lead, fused	*125.*		Ohms
Calido, solid	100.	Nichrome II	128.	Graphite (b)	0.00058
Krupp metal, solid	115.	Antimony (b), fused	136.	Graphite (a)	0.00089
Nichrome II, solid	119.	Bismuth, fused	*107.5*	Carbon (d)	0.0016
Bismuth, fused	130.9		Ohms	Carbon (a)	*0.0022*
Antimony, solid	152.	Graphite (b)	0.00065	Carbon (b)	*0.0029*
	Ohms	Graphite (a)	0.00086	Nernst filament, about	0.5
Graphite (b)	0.00080	Carbon (d)	0.0021	Refrax	*0.5*
Graphite (a)	0.00084	Carbon (a)	*0.0024*	Silfrax B	0.7
Carbon (a)	0.0027	Carbon (e)	0.0030	Carbon grains (b)	*0.85*
Carbon (d)	0.0028	Carbon (b)	0.0034	Graphite grains	*1.9*
Carbon (e)	0.0033	Carbon powder	0.12	Kryptol	3.4
Carbon (b)	0.0037	Silfrax B	0.84	Alundum, about	750.
Carbon powder	0.22	Sodium chloride, fused	*0.90*		
Silicon	0.094 to 0.23	Glass, roughly about	*1.*		
Lead chloride, fused, 520°	0.418	Graphite grains	1.7		
Silver chloride, fused	0.547	Carbon grains (b)	1.9		
Lead chloride, solid	0.824	Carbon grains (a)	*2.8*		
Silfrax B	0.92	Silicon powder	3.5		
Copper chloride, fused	2.50	Refrax	3.7		
Graphite grains	2.70	Kryptol	4.8		
Carbon grains (b) about	4.8	Porcelain, about	15.		
Carbon grains (a) about	8.5	Manganese oxide powder	15.7		
Kryptol	10.	Copper oxide CuO, powder	18.		
Refrax	19.7	Zinc oxide powder	26.7		
Boron, about	60.	Iron oxide, Fe_3O_4 powder	31.4		
Silicon powder	120.	Quartz	110.		
Glass about	330.	Magnesium oxide, powder	1400.		
Iron oxide, Fe_3O_4 powder	1260.	Alundum	8000.		
Copper oxide, Cu_2O, powder	1570.				
Manganese oxide, MnO_2, powder	2200.				
Copper oxide, CuO	5640.				
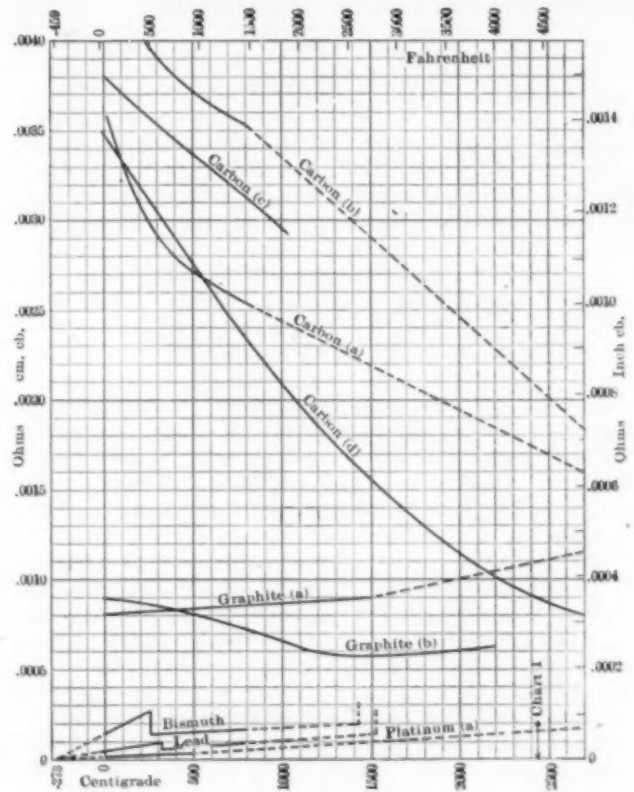
tionate error in the thermometer scale, or something foreign to the real resistivity.

Owing to the fact that on account of their wide range, the values cannot all be plotted on the same chart, Table I is here added, giving the materials and their values in the order of their magnitude for the different temperatures, 500, 1000 and 1500° C., which might be termed, roughly, incipient red heat, bright red heat, and dazzling white heat respectively. In some cases the values are probably only crude approximations, hence should not be relied upon as anything more than showing the order of magnitude. Those given in italics are exterpolations and are, therefore, only probable.

Vapors are used as resistors in the ordinary arcs with carbon and other materials as electrodes, the vapors then being those of the electrode materials. Also in the mercury lamp, and in Moore tubes, Geissler tubes, etc. Figures were, however, not available, it being evidently incorrect to calculate the resistance from the voltage and current, because part of this voltage is or may be a counter electromotive force, and represents (when multiplied by the current) the energy of vaporization, including what is often called the latent heat of vaporization. Very grave errors might, therefore, be made by neglecting this important factor, and it is not always an easy matter to eliminate it. In some cases, like Geissler tubes, this factor is absent, but there may then be others like contact resistance, ionization, imparting velocities to ions, etc., all of which must involve some energy consumption which would be represented in the electric circuit by a counter-electromotive force. It might be argued that a condensation of vapor occurs at the other electrode and that there would then be an equal direct electromotive force counteracting the counter one. It is a question, however, whether such condensation actually produces an emf, and, moreover, it is known that some if not most of the condensation in the mercury lamps does not take place at the electrode, but by a pure condenser action which does not return the energy to the electric circuit. And in the carbon arc much of the vapor is burned, hence its energy is lost to the
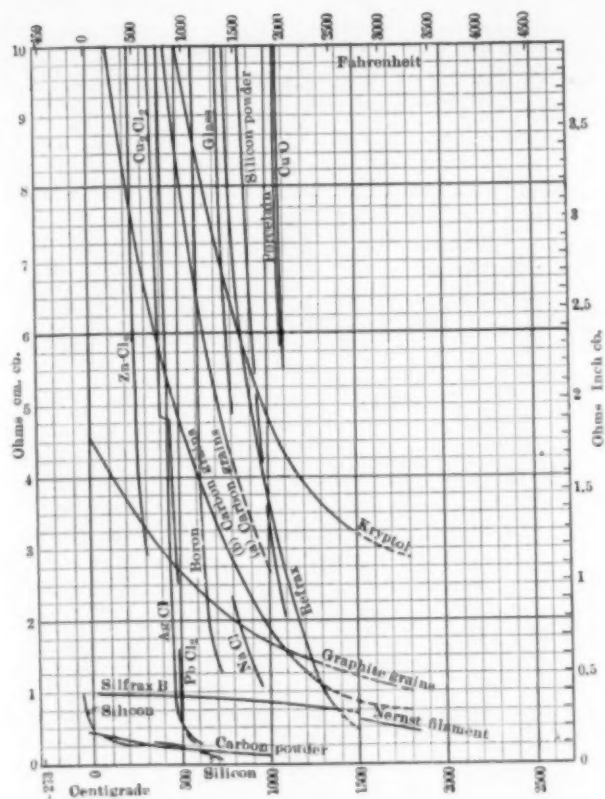
CHART 3

CHART 4

CHART 5

system. In a recent lecture Dr. Northrup announced that he expected to study this interesting question of the resistivity of vapors.

One of the curious features brought out by the present curves, if any dependence can be placed on exterpolations, is that bismuth at its boiling point may have a lower resistivity than the solid metal just before melting.
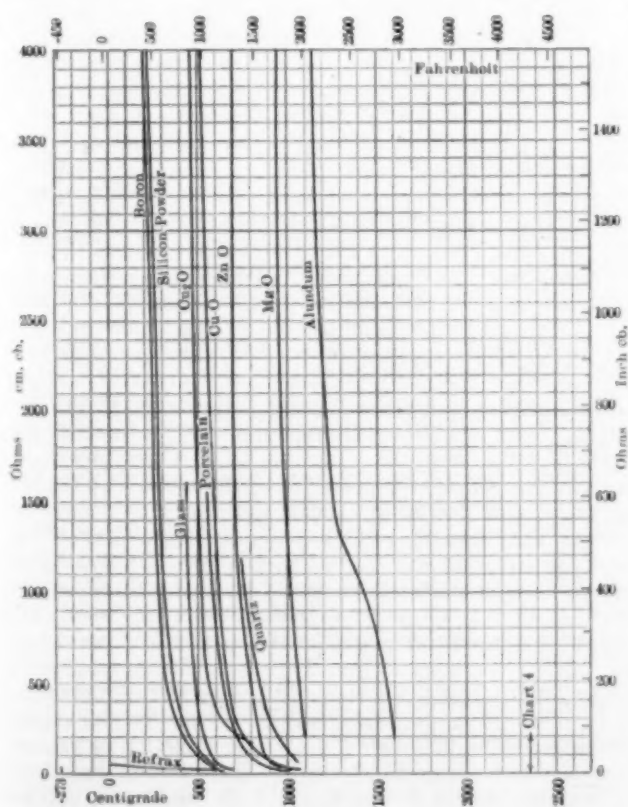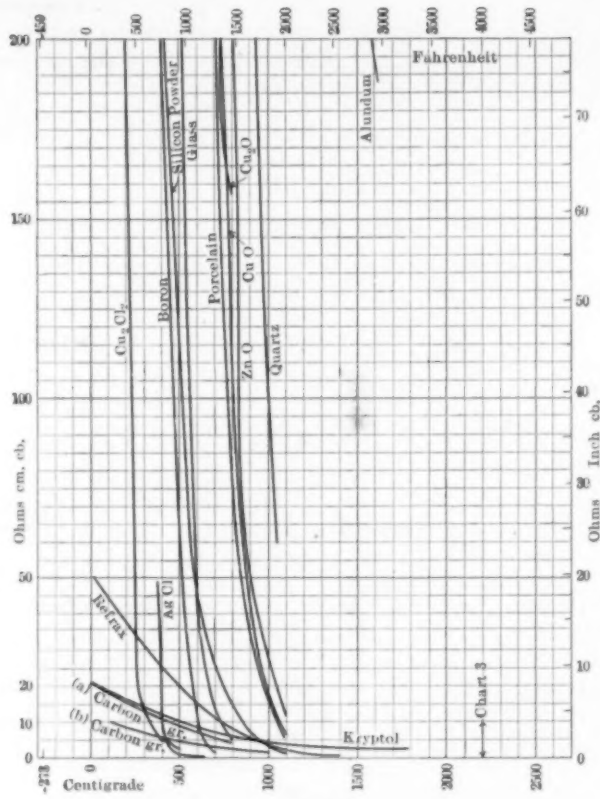
Northrup's recent determinations of the resistivities of molten metals, which are probably the best and most accurate, seem to have shown that these resistivities, for most metals at least, increase linearly; zinc and cadmium again are marked exceptions, behaving more like alloys than pure metal. If this linear increase is correct, interest naturally lies in seeing where these lines if prolonged downward would intersect the X axis, and especially whether they then meet at the same point. The present diagram enables this to be done, and it will be seen that most of them meet or nearly meet at what would be about — 1600 deg. C. Tin, copper, and aluminium meet strikingly closely at this point, while gold does so quite closely, lead and silver fairly close, bismuth deviating most, though not greatly.

Northrup's values are for constant volume and are, therefore, what they purport to be, namely, the resistance of a cube of 1 cm at the specified temperature. Presumably, however, most liquid metals expand with temperature, as illustrated by mercury in a thermometer; hence if it were known at what rate they expand, it would be possible to deduce the resistivity of a constant *quantity*, weight, or mass, assuming it to expand linearly only, like mercury in a thermometer tube. Such a correction would make the lines steeper, as the resistivity would then increase more rapidly with the temperature, and these lines would then converge to a point nearer to absolute zero, but the expansion would have to be far greater than it seems to be, to bring the lines to this zero. It is of interest to note in this connection that in measuring and stating the temperature coefficient of the resistivity of solids, this factor of the change of volume with temperature is generally neglected, being too small; and when the test is made between two marks on a wire, the result is not really for constant volume but for constant quantity. A correction for constant volume might then possibly straighten out the lines of some of them which are now curved. Northrup, in a recent lecture (*Trans.*, Amer. Electrochem. Soc., Vol. 25, pages 387-8) makes an interesting comparison concerning the cubical expansion

of six liquid metals, tending to show that the ratios of their coefficients of resistance to their coefficients of cubical expansion, are nearly the same, namely, about 4.

In the discussion, Dr. J. W. Richards (page 390) makes some further suggestions concerning a possible relation between latent heat of fusion and the ratio of resistivities at the melting point.

NOTES ON THE CURVES

(Centigrade degrees and resistivities in microhm, centimeter cube units, unless otherwise stated. L. and B. means the Landolt & Boernstein tables.)

Silver. Pure. Probably very accurate determinations. Northrup. *Jour. Frank. Inst.*, July, 1914, p. 85. Melts at 960.5 deg. C. or 1761 deg. Fahr.; boils at 1955 deg. C. or 3550 deg. Fahr. At 20 deg., 1.659 microhms, cm cube; 60 deg., 1.900; 960.5 solid 8.4, fused 16.6; 1000 deg., 17.01; 1100 deg., 18.19; 1200 deg., 19.36; 1300 deg., 20.54; 1340 deg., 21.01. Increase, solid, 0.60 microhm per 100 deg.; liquid, linear increase, 1.177 per 100 deg. Temperature coefficient, liquid, 0.00069. Exterpolated to boiling point 1955 deg. C. 28.

Copper. Probably very accurate determinations. Northrup. *Jour. Frank. Inst.*, January, 1914, p. 1. Melts at 1083 deg. C. or 1981.5 deg. Fahr.; boils at 2310 deg. C. or 4188 deg. Fahr. At 20 deg., 1.7347; 1083 deg. solid 10.2, fused 21.3; 1100 deg., 21.43; 1450 deg., 24.22. Temperature coefficient when molten, from 1100 deg. to 1340 deg, 0.000381, based on 1100 deg. as the datum. Exterpolated to boiling point, 31.5.

Gold. Probably very accurate determinations. Northrup. *Jour. Frank. Inst.*, March 1914, p. 287. Melts at 1063 deg. C. or 1945.5 deg. Fahr.; boiling point not known. At 20 deg., 2.316; 1063 deg. solid, 13.50; fused, 30.82; 1500 deg., 37.0. Increase per degree when molten, 0.014142.

Aluminium. Northrup. *Transactions Amer. Electrochem. Soc.*, April, 1914, p. 380 and 388. Melts at 658.7 deg. C. or 1217.7 deg. Fahr.; boils at 1800 deg. C. or 3272 deg. Fahr. Just before fusion, 12.5; just after, 20.13; 1120 deg., 25.

Brass. Cu., 63; Zn., 34.6; Pb., 2.4. Northrup. *Met. & Chem. Eng.*, March, 1914, p. 161. Presumably carefully made determinations. Melts about 900 deg. C. or 1652 deg. Fahr. Just before fusion, 17.5; just after, 41.62; 1100 deg., 40.

Molybdenum. Fink. *Trans. Amer. Electrochem. Soc.*, Vol. 17, p. 229. Melts at 2500 deg. C. or 4500 deg. Fahr. Annealed, at 0 deg., 4.8; hard, 5.6. Temperature coefficient per degree, 0.0050.

Tungsten (a). Fink. *Trans. Amer. Electrochem. Soc.*, Vol. 17, p. 229. Melts at 3000 deg. C. or 5430 deg. Fahr. Annealed at 0 deg., 5.0; hard drawn, 6.2. Temperature coefficient per degree 0 to 170 deg. C., 0.0050.

Tungsten (b). Pirani. *Tables Annuelles*, Vol. 1, p. 227. Old lamps. Gives ratios at various temperatures up to 1500 deg. C., to value at 20 deg. C. Latter here assumed to be 5.55 as given by him, p. 220.

Cadmium. Probably accurate determinations. Northrup. *Jour. Franklin Inst.*, February, 1913, p. 153. Melts at 320.9 deg. C. or 609.6 deg. Fahr. Boils at 778 deg. C. or 1432 deg. Fahr. At 0 deg., 7; at 321 deg., solid, about 17.1; liquid, 33.77; 700 deg., 35.78. Exterpolated to boiling point, 36.5.

Platinum (a). L. & B. Melts at 1755 deg. C. or 3191 deg. Fahr. At 0 deg., 11.0. Temperature coefficient, a = 0.00394, b = 0.000000584, between 0 deg. and 500 deg. C. The exterpolated values are probably only very crudely approximate.

Platinum (b). Pirani. *Tables Annuelles*, Vol. 1, p. 227. Gives ratios at various temperatures up to 1600 deg. C., to values at 20 deg. C. Latter here assumed to be 9.6 as given by him, p. 219.

Tantalum (a). Siemens. Melts at 2850 deg. C. or 5160 deg. Fahr. At 0 deg., 14.6. Temperature coefficient in per cent per degree 0 deg. to 100 deg., 0.33; 100 deg. to 1850 deg., 0.29.

Tantalum (b). Pirani. *Tables Annuelles*, Vol. 1, p. 227. Gives ratios at various temperatures up to 2000 deg. C., to values at 20 deg. C. Latter here assumed to be 14.6. At 2000 deg. it is 92.5.

Zinc. "Reagent zinc." Probably accurate determinations. Northrup. *Jour. Frank. Inst.*, Feb., 1913, p. 153. Melts at 419.4 deg. C. or 786.9 deg. F. Boils at 920 deg. C. or 1688 deg. Fahr. At 0 deg., 6; at 419 deg. solid, 17; liquid, 37.3; 850 deg. 35.74. Exterpolated to boiling point, 36.

Tin. Nearly pure. Probably very accurate determination. Northrup. *Jour. Frank. Inst.*, Feb., 1913, p. 153. Melts at 231.9 deg. C. or 449.4 deg. Fahr.; boils at 2270 deg. C. or 4118 deg. Fahr. At 0 deg., 11; 225 deg., 22; 235 deg., 47.60; 750 deg., 61.22. Liquid, linear increase, 2.61 per 100 deg. Exterpolated to 2000 deg., 93.8.

Iron (a). Melts at 1520 deg. C. or 2768 deg. Fahr., probably meaning pure iron; boils at 2450 deg. C. or 4442 deg. Fahr. This curve gives only crude approximations; pure iron being never used, accuracy is of no importance. The resistivity at zero was taken as 8.56 for pure iron as a mean of two values in L. & B. The rise with temperature based on that at zero was taken from the curve by Somerville, *Physical Review*, Vol. 31, p. 268, which values appear to have been determined with care, but they are unfortunately not given either as resistivities nor even in ohms, but merely relatively. The value when molten is a crude determination by the writer, of ordinary steel. The rise after melting is mere exterpolation, based on the general converging lines of other metals, no importance should be given to it. The bend in the curve at the point of recalescence is of interest.

Iron (b). Vom Baur. Molten iron and steel. No temperature given.

Ferro-nickel. 50 + 50. L. & B. at 0 deg., 36; 600 deg., 100; 1000 deg., 105.

Rose Metal. L. & B. Melts at 94.3 deg. C. At 0 deg., 64.5; at 93.5 deg., 78; at 250 deg., 80.4; at 350 deg., 83.3. The small fall at the melting point is exterpolated from the curves before and after; it may not be correct; it contains much bismuth which has a very great fall at its melting point.

Lead-Tin Alloy. 75.78 Pb, 24.22 Sn. Mueller. *Tables Annuelles*, Vol. 1, p. 222. Congeals at 263.8 deg. C. At this temperature 73.2; at 1000 deg. C., 98. Note that though an alloy the line seems straight.

Lead. "Test lead" free from silver. Probably very accurate determinations. Northrup. *Jour. Frank. Inst.*, February, 1913, p. 153. Melts at 327.4 deg. C. or 621.1 deg. Fahr. Boils at 1525 deg. C. or 2777 deg. Fahr. At 0 deg., 24; at 327 deg. solid, about 49.2; liquid 94.7; 800 deg., 116.20. Exterpolated to 1000 deg., 125, to 1500 deg., 148.

Calido. Elec. Alloy Company. Melts above 2800 deg. Fahr. or 1530 deg. C. Wire 0.010 in. diameter has 5.75 ohms per foot. Temp. coeff. 0.00019 deg. Fahr.

Krupp Metal, Nickel Steel. Thomas Prosser & Son. Maximum safe temperature 600 deg. C. or 1112 deg. Fahr.; at 20 deg,, 85.13. Temperature coefficient, presumably from 0 deg. to 600 deg. C., 0.0007007.

Woods Metal. L. & B. Melts at 69.8 deg. C. or 157.5 deg. Fahr. At 0 deg., 51.8; 50.3 deg., 57.8; 75 deg., 85; 350 deg., 109.5. Note that it rises considerably at the melting point, although it contains much bismuth.

Nichrome II. Driver-Harris Company. Maximum safe temperature 2000 deg. Fahr. or about 1100 deg. C. At 20 deg. C., 660 ohms per mil-foot. Temperature coefficient, 0.00009 per Fahr. deg.

Bismuth. Nearly pure. Probably very accurate determination. Northrup. *Jour. Frank. Inst.* February, 1913, p. 153. Melts at 271 deg. C. or 520 deg. Fahr.; boils at 1430 deg. C. or 2606 deg. Fahr. At 17.5 deg., 120; 271 deg. solid 267, liquid 127.5; 750 deg., 153.55. Exterpolated to boiling point 191.

Mercury. L. & B. Melts at — 40 deg. C. or — 40 deg. Fahr.; boils at 357 deg. C. or 675 deg. Fahr. At — 183.5 deg., 6.97; at — 40 deg., about 29; at 350 deg., 135.

Antimony (*a*). Nearly pure. Before fusion the values are only approximate. Northrup. *Jour. Frank. Inst.* February, 1913, p. 153. Melts at 630 deg. C. or 1166 deg. Fahr.; boils at 1440 deg. C. or 2624 deg. Fahr. At 650 deg, 117.07; 900 deg., 131.0. Exterpolated to 1000 deg., 158.

Antimony (*b*). Bornemann & von Rauschenplat. *Tables Annuelles*, Vol. 3, p. 258. Only after fusion. Exterpolated to boiling point, 145.

Graphite (*a*). Acheson Company. At 20 deg., 0.000320 ohm, inch cube. Resistivity according to Northrup, increases about 9 to 10 per cent from 20 deg. to 1500 deg., and more rapidly thereafter. Exterpolated part continued to the graphitization point here assumed roughly as about 0.0013 at 3300 deg., where this curve should meet those of carbon.

Graphite (*b*). Hansen. *Trans. Amer. Electrochem. Soc.*, Vol. 16, p. 329. Here based on his percentage values, p. 334, and what he seems to assume as the mean room temperature value, p. 339, namely, 0.00035 ohm, inch cube.

Carbon (*a* and *b*). National Carbon Company. Fine-grained electrodes (*a*) 20 deg. C., 0.0014 ohm, inch cube; 400 deg., 0.0011; 800 deg., 0.0010. Coarse-grained electrodes (*b*) 20 deg. C., 0.0020; 400 deg., 0.0015; 800 deg., 0.0014. At higher temperatures they say it changes by a linear function to the graphitization point, here assumed roughly as about 0.0013 at 3300 deg., hence the exterpolated curves have here been continued to this point where the curves should meet those of graphite.

Carbon (*c*). Somerville. *Physical Review*, Vol. 31, from the apparently well-determined temperature curve on p. 270, where, however, the values are only relative; 0.0038 ohm was here assumed as the basic value at zero, as he gives no actual resistances.

Carbon (*d*). Hansen. *Trans. Amer. Electrochem. Soc.*, Vol. 16, p. 329. He calls attention to the variability of the resistivity of cold carbon, depending upon what temperature it had been raised to while in use, the higher temperatures graphitizing it more or less. The present curve is the "parent curve" in his Fig. 3, based on the value 0.00137 ohm, inch cube, cold, which he seems to have used.

Carbon Grains (*a*). National Carbon Company. Sifted through 4 mesh and resting on 6 mesh, not tamped. At 20 deg. C., 8.2 ohms, inch cube; 800 deg., 1.7.

Graphite, Carbon (*b*) *and Kryptol Grains.* Jeffries. METALLURGICAL & CHEMICAL ENGINEERING, March, 1914, p. 154. Grains passing through 0.093-in. mesh and remaining on 0.0328-in. mesh. No pressure.

Silicon. Zimmerman. *Tr. Am. Electrochem. Soc.*, Vol. 15, p. 395. Very variable. Resistivity decreases rapidly with increase of temperature. Melts at about 1430 deg. C.

Carbon and Silicon Powders. Somerville. METALLURGICAL & CHEMICAL ENGINEERING, August, 1912, p. 484. Passed a 40-mesh screen. Column under about 3 lb. pressure. Results given as curves only. The carbon powder had about fifty times the resistivity of solid carbon, and the powdered silicon about 25,000 times that of solid silicon. Powders were placed and meas-

ured in porcelain tube. The present curve for poreclain (by the same author), however, shows that at the higher temperatures the resistivity of the tube was of approximately the same order of magnitude as that of the silicon powder, hence it would seem that the error introduced by the tube must have been quite great.

In the *Electrical World*, May 25, 1912, p. 1118, the same writer gives measurements on carbon and silicon powder the size of sand to fine dust, under various pressures. Carbon under no pressure, about 0.20 ohm; hence about fifty times that of solid carbon. Silicon under pressure of about 30 kg per sq. cm about 0.40 ohm; under no pressure it has about 500,000 times the resistivity of solid silicon. No curves are here given, as the data were all determined at room temperatures.

Silfrax B. Carborundum Company. Maximum safe temperature about 1800 deg. C. At 20 deg. C., 1.0 ohm, cm cube; 1400 deg., 0.7.

Refrax. Carborundum Company. Maximum safe temperature about 2100 deg. C. At 25 deg., 50 ohms, cm cube; 1400 deg., 0.65.

Nernst Filament. Wurtz. *Trans. Am. Inst. Elec. Eng.*, Vol. 18, p. 545. Length, 25 mm; diameter, 0.63 mm; 196 volts, 0.5 amp, hence 0.49 ohm, cm cb. No temperature given.

Zinc Chloride. $ZnCl_2$. L. & B. Melts at 262 deg. C. or 505 deg. Fahr. At 230 deg., infinity; just melted, 4.46 ohms; 310 deg., 290; results not very concordant.

Silver Chloride. AgCl. L. & B. Melts at 460 deg. C. or 860 deg. Fahr. At 380 deg., 47.6 ohms; 500 deg., 0.547 ohm; 650 deg., 0.214 ohm.

Copper Chloride. Cu_2Cl_2. L. & B. Melts at 434 deg., C. or 813 deg. Fahr. At 140 deg., 1000 ohms; 250 deg., 29 ohms; 400 deg., 4.83 ohms; 440 deg. (melted), 4.79 ohms; 490 deg., 2.52 ohms. Note that the resistivity appears to remain nearly the same for a while about the melting point.

Lead Chloride. $PbCl_2$. L. & B. Melts at about 500 deg. C., 932 deg. Fahr. At 500 deg., solid, 0.824 ohm; 520 deg., melted, 0.418; 580 deg., 0.372.

Sodium Chloride. NaCl. L. & B. Melts at 790 deg. C. or 1454 deg. Fahr. Freezing, 2.28; melted at 960 deg. C., 1.087.

Boron. Weintraub. *Trans. Amer. Electrochem. Soc.*, Vol. 16, 1909, u. 165. Only approximate. Melts at 2000 to 2500 deg. C. At 23 deg., about 1.7 megohms; at dull red heat, here taken as about 700 deg., a certain piece had a resistance of about 5 ohms, which would be roughly about 1.5 ohms, cm cube. The present curves are in a range where but few values were given by him, hence indicate but little more than the general order of magnitude.

Glass, Porcelain and Quartz. Somerville. *Physical Review*, Vol. 31, 1910, p. 261. Presumably good determinations. No figures are given for resistivities, only curves. Good data for temperature coefficients. Berlin porcelain begins to soften at about 1100 deg. C. It seems that all three of these materials were still solid over the ranges given. For quartz, the logarithm of these resistivities plotted against temperatures, gives a straight line. The values for glass plotted as conductivities do not give a straight line.

Various oxides in powder form. CuO, Cu_2O, MgO, ZnO, Fe_2O_3, and MnO_2. Somerville. METALLURGICAL AND CHEMICAL ENGINEERING, July, 1912, p. 422. The curves in the original article give the actual resistances and not the resistivities, although not so stated. They are here reduced to resistivities, and are only approximate, as accurate data for the reduction were not given. Pressure 2 to 4 lb. on a column 1 cm diameter. The powders were measured while in porcelain or quartz tubes, but as the present curves show that the latter materials have resistivities of about the same order of

magnitude at the same temperatures (according to the same author) an error of considerable magnitude must have been involved, hence they may not even be of this order of magnitude; the tests were therefore like measuring the resistivity of mercury in a copper or iron tube. The present compilation brings out just such features. The values for Fe_2O_3 and MnO_2 were so nearly like those for ZnO that the curves have been omitted. CuO melts at 1084 deg. C. or 1984 deg. Fahr. (almost exactly the melting point of copper); Cu_2O decomposes at 800 deg. C. or 1472 deg. Fahr.

Alundum. Grade RA 355. Al_2O_3. Fused bauxite. Northrup. METALLURGICAL AND CHEMICAL ENGINEERING. February, 1914, p. 125. Presumably a reliable determination. Melts at 2050 to 2100 deg. C. At 1600 deg., 190 ohms.

Philadelphia, Pa.

Has Titanium Any Influence on the Properties of Steel?

BY F. A. J. FITZGERALD

For several years the writer has frequently been asked the question: "Has titanium really any influence on the properties of steel?" The question has invariably been answered in the affirmative because of the evidence furnished by actual experiments and that gleaned from the voluminous and apparently trustworthy literature on the subject. For some reason, however, there undoubtedly exists a great deal of scepticism on the subject.

The reason for this scepticism is not very difficult to find for it obviously lies in certain characteristics of the manufacture of steel which are analogous to the older practice of medicine, a practice which indeed may exist in some quarters even to this day. There used to be, in the old days of medical practice, a wonderful form of treatment known as the "blunderbuss prescription," which consisted of as many constituents as the ingenuity of the doctor could combine with due consideration of the laws of compatibility. Usually there could be no question whatever as to the effect of the exhibition of the medicine as a whole, but for obvious reasons it was extremely difficult to separate the reactions of the various constituents. Now to the layman it certainly appears that the doctoring of steel is often governed by the methods of the blunderbuss school, and to this is added a large number of accidental occurrences which certainly influence the final product, and consequently make it extremely difficult to correlate various causes and effects.

No one watching a series of heats run off in a steel mill can fail to recognize the number of things happening during the manufacturing process which must affect the steel ingots. The temperature of the metal involves generally the personal equation of the melter, the rate at which the moulds are filled is apt to vary, there may be running stoppers, the way in which the steel is doctored by sundry additions varies. In the case of small heats you may sometimes see a melter make additions of substances which he conceals about his person and which may or may not influence the final result. Under such conditions it might be expected that the final product of the manufacture will show considerable variations when different heats are examined, and this is certainly found to be the case.

Probably no one will deny that it would be a great advantage if we could use perfectly pure and suitable materials for the manufacture of steel, melt these under uniform and perfectly controlled conditions and so eliminate the objectionable doctoring of the metal, whether by the blunderbuss or more scientific methods. This, however, is unfortunately impossible and, therefore, since doctoring must be done it should be as nearly scientific as possible. There cannot be any doubt at all that the great difference of opinion as to the effect of various additions used in the manufacture of steel is due to the ways in which the medication is exhibited and to the attention to or disregard of the laws of compatibility. Even when a single steel mill, where a more or less uniform practice is followed, is considered, it is impossible to avoid many variables, so that in order to arrive at conclusions about the effect of any one addition, such as titanium, it is necessary to make a sort of statistical investigation.

An article which recently appeared in the *Railway Age Gazette*[1] mentioned some tests which apparently would lend themselves to an inquiry of this sort, and the Titanium Alloy Manufacturing Co. allowed the writer to examine a number of records covering these tests. From these data were obtained which on analysis seem to show beyond a doubt that the addition of titanium to steel has an important influence on its properties. The data are derived from very complete reports on 155 heats, representing the production of over
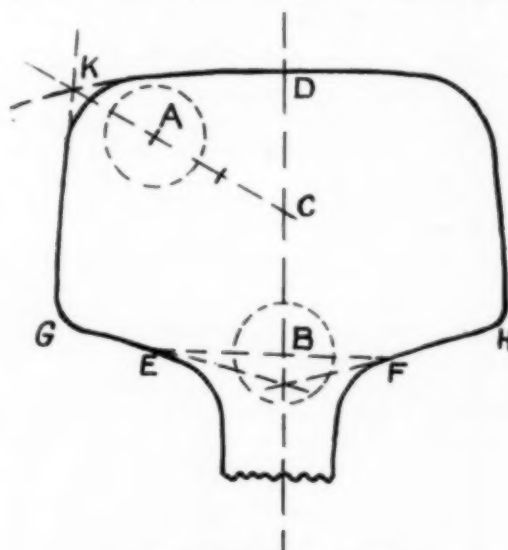
FIG. 1—SECTION OF RAIL

9000 tons of 100-pound steel rails, all made at the same mill and under as uniform conditions as could be expected. In 78 heats no addition of titanium was made, while in 77 heats ferro-titanium was added in the ladle. Here, then, there appears to be a sufficient number of observations on a large enough scale to eliminate to a great extent the effect of variable errors.

As everyone knows, the rail problem is a very serious one and an immense amount of study has been devoted to its solution. It seems to be believed by a great many authorities that segregation is one of the chief causes of trouble, and with this in view a method of detecting segregation has been proposed for use in the specifications for rails. Referring to Fig. 1, which represents a section of a rail, drillings are taken at places indicated by the circles A and B. The centres of B and A are found respectively as follows:

The points E and F are where the lines G E and H F leave the edge of the section. The line E F is drawn and bisected at B, which is the centre of the circle.

The line B D is drawn along the axis of symmetry of the section and bisected at C. The point K is the intersection of the prolongation of the curve D K with the line G K. Join C and K and then the centre A is found at two-thirds of the distance of C from the intersection of C K and the edge of the section.

[1]October 23, 1914.

The samples for analysis are made with a ⅝-in. drill and used for carbon determinations.

In the proposed specifications these samples are taken from A rails, i.e. the first rails made from the heads of the ingots after a 9 per cent crop. In general the carbon in the sample at B is found to be higher than that in sample A and it is suggested that whenever the carbon in B is more than 12 per cent greater than that in A the rail should be rejected. In the 155 heats under consideration this method of testing was used, since it was maintained that the use of titanium diminished segregation. Accordingly from every heat the Titanium Alloy Manufacturing Co. took the nineteenth ingot for applying the test and the Steel Co. took the eighteenth for a check test.

There are various ways in which the results obtained may be shown, but they are best illustrated by the dia-

FIGS. 2 AND 3—DIAGRAMS OF RESULTS OBTAINED WITH HEATS OF STEEL WITHOUT AND WITH USE OF FERROTITANIUM

grams of Fig. 2. In order to make the diagrams the various heats were divided up into seven groups as follows:

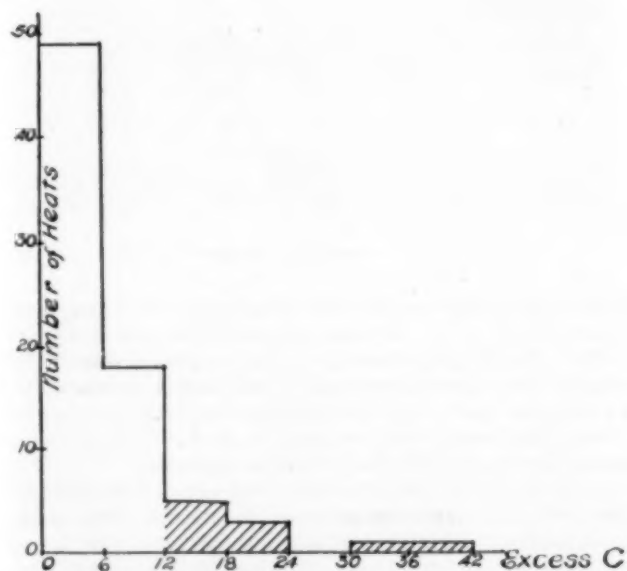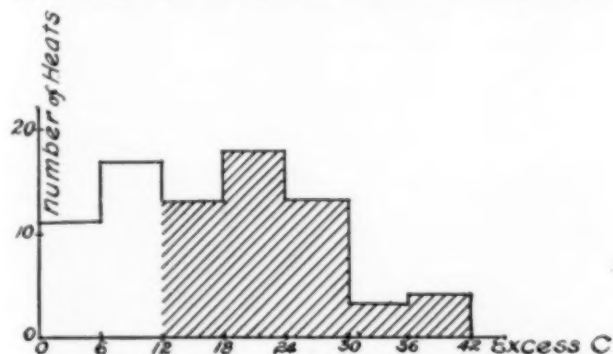| Group No.	Per cent excess of C. in web
1	6.0 or less
2	6.1 to 12.0
3	12.1 to 18.0
4	18.1 to 24.0
5	24.1 to 30.0
6	30.1 to 36.0
7	36.1 to 42.0

The number of heats falling in each group was then determined and from these the diagrams were drawn. The upper diagram shows the results obtained in the 78 heats where no titanium was used and the lower dia-

gram the results from the 77 heats where titanium was used. In each case the shaded portion shows the heats where the carbon is in excess of the limit set by the proposed specification.

The test shows that where no titanium was used only 36 per cent of the heats gave A rails which came within the proposed specification limits, while with the use of titanium 87 per cent. would pass.

A more detailed examination of the 77 heats in which titanium was used clearly shows the influence the amount of titanium added has on the results. According to the advice of the Titanium Alloy Manufacturing Co. the amount of ferro-carbon-titanium used should be such that the quantity of metallic titanium added to the steel is 0.10 per cent. This, however, was not followed as in some heats only 0.075 per cent was added and in some as little as 0.053 per cent. The following table shows the effect of the amount of titanium added:

Titanium added. Per cent	Total Heats	Heats within specification limit. Number	Per cent
0	78	28	36
0.053	7	3	43
0.077	39	33	84
0.10	81	31	100

This seems to show that in order to get the best results at least 0.10 per cent of metallic titanium should be added.

While it may be argued that, as regards the amount of titanium which should be added, it is necessary that a larger number of experiments be made to determine the proper dose, there cannot be the least doubt that the question originally asked must be answered in the affirmative.

The FitzGerald Laboratories, Inc.,
Niagara Falls, N. Y.

Findings of the Selby Smelter-Smoke Commission

The Selby Smelter Commission appointed to settle the controversy between the Selby Smelting & Lead Company and the residents of Benicia, Cal., and contiguous agricultural territory, has filed its report with the Superior Court of Solano County, Cal. The commission comprised J. A. Holmes, director of the U. S. Bureau of Mines; E. C. Franklin, professor of organic chemistry, Leland Stanford, Jr., University, and Ralph A. Gould, chemical engineer, of San Francisco. The purpose of the commission was to determine whether the smelter was operating in violation of the court decree of July 16, 1908; the extent of violation, if any; and the manner of operation necessary to avoid violating the decree. A large corps of experts was employed to make various investigations. The commission has found that the smelter violated the decree with respect to damage to certain horses up to April, 1914, at which time a baghouse was installed and operated. No violation is found with respect to disagreeable odor, or as to damage to vegetation. It is stated further, that the decree will not be violated if less than 80 tons of SO₂ is discharged into the air in 24 hours. One of the interesting findings of the commission was to the effect that sulphurous gases from Dwight-Lloyd roasters could be concentrated by recirculation to the extent of 7.5 per cent SO_2, making it possible to produce sulphuric acid from the gas.

Missouri led all other states in the production of lead and zinc in 1913, according to figures compiled by the U. S. Geological Survey, although the production for the past year was less than that of 1912 due to a smaller output of zinc and decline in price for that metal. The total value of lead and zinc concentrates in 1913 was $21,109,358. Based on metallic content, the value was $29,494,064.

The Hardwood Distillation Industry in America*

BY EDWARD H. FRENCH AND JAMES R. WITHROW

In view of the economic importance of the utilization of wood waste, and the increasing interest being manifested in this utilization, it naturally surprises the inquirer that there is practically no literature upon this industry from the point of view of actual American practice. It may not be without value, therefore, to consider the progress made in hardwood distillation and to trace its development from its inception in this country. We have gathered together consequently and classified much of the information which we have acquired in the plants of this industry during an experience in its totalling about twenty-five years.

This tracing of the development of an industry of the magnitude of this one is peculiarly interesting to the engineer, since it shows the necessarily slow evolution of the industry in the hands of the unscientific manipulator, and serves to emphasize the advantages with which the modern chemical engineer is possessed, and serves also to indicate how much more rapid the development might have been in the hands of experienced chemical engineers. It indicates also that the future may, under the direction of the competent engineer, make advances of importance much more rapidly than in the past. This latter statement is significant when it is remembered that the advances made thus far have been due either to accidents or very often to workmen endeavoring to minimize the laboriousness of their work. As plants are operated on 12-hour shifts, this desire to economize energy may be readily understood.

For much of the historical information collected we desire to express our appreciation to Mr. Robert Mackay, who has been active in this industry for so many years. In fact, during the past fifteen years our own continued intimate acquaintance with Mr. Mackay has been not only of unusual pleasure but of continuous instruction. A history of this industry would be incomplete without mention of the fact, that due largely to his personality and integrity, the firm with which Mr. Mackay is identified, has had the unusual experience, in an extensive industry, of supplying engineering materials for every plant of this nature in the United States and Canada with perhaps two exceptions, for a period covering the past 25 years.

Early History

While charcoal burning was doubtless carried on in the earliest days in this country it was not until 1830 that James Ward began the manufacture of pyroligneous acid, at North Adams, Mass., according to Monroe and Chatard (12th Census, United States, Bull. No. 210, Chemicals and Allied Products, p. 34). No claim is made that the pyroligenous acid was carried further, though it may have been. We have ourselves no information on this matter other than the above citation. As far as we can ascertain it was not until 1852 that works in the modern sense were inaugurated for the distillation of wood for the production of volatile products, and their semi-refined products. This does not appear in agreement with W. L. Rowland (Special agent 10th U. S. Census on Chemical Products and Salt, p. 23) who is later cited by Monroe and Chatard (Ibid) and C. L. Campbell, METALLURGICAL AND CHEMICAL ENGINEERING, 1910, p. 155, all of whom state that the manufacture of acetate of lime and methyl alcohol was started in the United States about 1867 by James A. Emmons and A. S. Saxon in Crawford County, Pa. Our information in this case comes from

various manufacturers who have been in this business from the earliest times or at least whose family connection with it goes back to the beginning. One of these sources is Mr. Neil Patterson, whose father was in charge of the original "Scotch Works," built in 1852. In this year The Turnbull Company of Glasgow, Scotland, who were engaged there in the copper and iron industry as well as that of wood distillation, built the first operation in this country, by way of expanding their old country business. The place chosen for this location was known as Milburn, New York, now Conklins Station, on the D., L. & W. R. R. not far from Binghamton.*

This Turnbull company brought with them their apparatus as well as men experienced with their methods. On account of these Scotch workmen the works became known as the "Scotch Works" and this name has clung to it to the present time, although the original workmen gradually went with new operations which started

FIG. 1—TYPICAL WOOD YARD IN PENNSYLVANIA

shortly after this one. They had much to do with the subsequent expansion of the industry, all of them being later in charge of new works.

It is interesting to note in connection with this first plant that it was a type that was copied in detail in the construction of those that followed, for many years afterward. All these plants were equipped with cast-iron cylinders 42 in. in diameter and 9 ft. long, set in pairs, thus each pair held about 1¼ cords of wood. The wood was cut 7 ft. long and the charge "run off" every 12 hours, and six days a week. The stills and pans were operated during these early days exclusively by direct firing. The fuel used for the retorts, stills and pans was the charcoal produced, over which was poured the residual tar to make a quick fire.

This original works was followed in 1865 by Emmons & Co., of Brookdale, N. Y. In 1868 Alonzo Smith started a plant at Sturroco, Pa.; Keery Brothers, Cadosia; Mandaville, Emmons, Corbett & Mitchell, Livingston Manor, N. Y.; King & Co., Acidalia, N. Y.; Hilton & Co., Hiltonville, N. Y.; Brand & Schlayer; Frink & Ross; Tyler & Hall; Inderlied & Co.; Bayless & Berkalue and Wright & Co. were also early in the field.

During the early part of this period of development the chief product desired was acetate of lime, for which from 12 to 15 cents per pound was obtained. The alcohol demand was almost negligible, that which was made was of very infeior quality and was kept in barrels, and most of it was lost by evaporation or through some "illegal vent." The charcoal also had but little commercial

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*A paper read before the Philadelphia meeting of the American Institute of Chemical Engineers on December 4, 1914.

*Mr. J. L. Stuart, of Corbett & Stuart, one of the earliest firms in this business in this country, informs us that the date 1852, given by Mr. Patterson for the building of the Turnbull plant, should be 1849.

value and was largely consumed as fuel at the works, although a small local demand gradually developed starting with the neighborhood tinsmith.

The change from the old charcoal heaps or pits to the kilns probably came quite early and perhaps before any of the improvements we have mentioned. It was not until 1876, after the retort system was well established and markets for its products had been developed, however, that Dr. H. N. Pierce's inventions made it possible to utilize partially the products wasted in the smoke from the charcoal kilns in Michigan, where great quantities of charcoal were prepared for blast furnace use.

The earliest attempt at refining alcohol, so that it might be of commercial value, was made by a Mr. Pollock, a chemist living just out of New York City. In a short time a demand began to develop for this product, which steadily increased, and up until 1880 was at all times up to the dollar mark. It was during this period that the need of better refining was felt, as it was realized that a large loss was entailed in the refining operations. This necessity accounts for the coming of the Burcey pans in the early seventies. These are copper containers placed in the vapor line above the stills, with

FIG. 2—CLOSE VIEW OF WOOD YARD

deflectors inside to project the vapor against the upper shell of the container, upon which a stream of water runs, causing fractional separation of the water from the alcohol vapor. The increase of alcohol product resulting from this improvement, together with the increasing market demand, made a central refinery necessary, and the producers united in building a refinery at Binghamton, N. Y., known as the Burcey Refining Company. This was in the middle seventies, and the plant is still in operation. It has served a good purpose, and to it was due perhaps more than to anything else the substitution of steam for direct fire distillation.

Before leaving this early history, it should be mentioned that the Turnbull plant, and, in fact, several succeeding plants, had but four pairs of retorts or 5 cords capacity to the charge, thus by obtaining two charges within twenty-four hours their total wood consumption was about 10 cords per day. To-day there are single plants operating 160 cords daily. Thus we have an illuminating comparison, at least so far as size is concerned, of the development of the industry.

Design of Apparatus

Even at the present time, there remain many plants using the old original retort system, with one very slight modification. Those first in service were of cast iron, while the later ones have shells of steel with riveted cast-iron necks and fronts. The purpose of this change

was due to the fact that in the early operations, since the wood was then of much less value than later, and high yields were not so important, it was charred at a very high temperature, in order to increase as much as possible the capacity of the plant by shortening the time of firing. As cast iron was much more durable for these high temperatures than steel, this use of cast-iron retorts was universally practiced. When, however, with the coincident rise in the cost of wood, it was found that lower temperatures gave an increase of all products, it was seen that steel could be employed to advantage, for its lower weight permitted the turning of the retort. This turning refers to the saving in apparatus universally practiced and consists merely in the removal of the brick setting when the side in contact with the fire becomes buckled, rolling over the retort, and placing the uninjured part next the fire, thus materially increasing the life of the retort. This modern retort is of uniform size and design in all plants which still use this type of apparatus. The shell, as originally, is 42 in. in diameter and 9 ft. long, supported at the ends in a cast-iron cradle and having a cast-iron front, with door and lugs for pinning the door shut. At the rear is a neck 10 in. in diameter with attached condenser.

The evolution of the condenser is especially interesting, in view of the fact that when the original condenser was installed each succeeding plant accepted it as being of proper size, and the new installation was made the same size. Then from time to time some one would discover that an addition would yield more product and at once the arbitrary sized unit was changed.
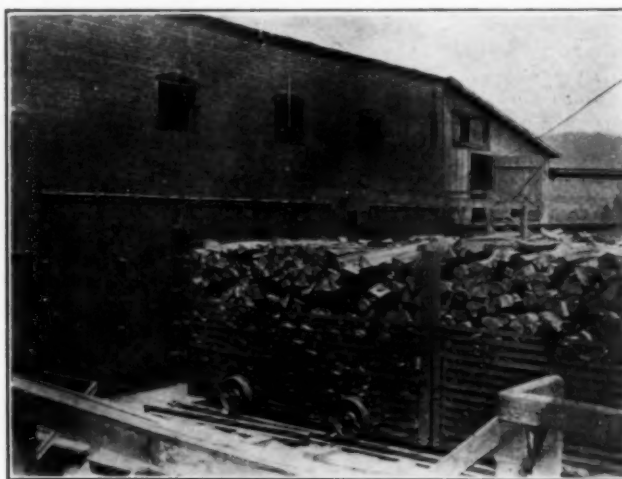
FIG. 3—LOADED WOOD CARS AT OVEN

Originally the worm condenser was used, but it soon became apparent that the heavy carbon bodies caused clogging, and soon the log condenser was substituted and was used until the introduction of the upright tabular one. These log condensers were made by attaching, by a copper tee, a large-sized copper pipe, called the log, to each pair of retorts. Near the ends of this pipe were copper connections, joining the large log to a smaller one, and this in turn was similarly connected with others progressively decreasing in size. The whole log condenser lay in a plane at an angle of 45 deg. and the whole was surrounded by a wooden box with water inlet at bottom and outlet at the top. The joints were simply slip joints and were slipped together and "sweeled"; that is, wrapped with a cloth liberally covered with red lead, which after becoming dry or "set" offered a suitable and effective joint. At the ends of the logs were removable slip joint caps, for cleaning purposes, thus the cleaning from the heavy tarry and carbonaceous bodies was easily accomplished.

The first really important change in the general style of operation was that of replacing the old retort by the oven, which was done in the middle nineties, and is claimed to have been first tried out at Straight Creek, Pa. This change was wholly mechanical, and consisted merely of substituting for the retort a large rectangular oven, equipped with rails on the bottom for the purpose of carrying cars. These cars were loaded with wood and could be quickly pulled in and out mechanically and the charcoal unloaded outside the oven, greatly increasing the economy in this part of the operation over the slow hand drawing of the charcoal of the retort system.

There appears to be, however, much more advantage in this style of operation than the mechanical advantages which were at first anticipated, as an increased yield of products is obtained, due undoubtedly in part to more advantageous manipulation, but in our opinion also to the different chemical reactions that take place. In the old retort system complete carbonization of the wood took place in about sixteen hours, and it required in the oven system twenty-four hours, yet the temperature of the gases at the neck are higher in the latter, running at a maximum under skilful manipulation to about 330 to 360 deg. C., while in the former case the operation was consummated at not over 290 deg. maximum. This maximum temperature is obtained about midway or two-thirds of the run, at which time a very decided exothermic reaction takes place, and care must be exercised that the liquor is not "burned"; that is, that the temperature is not permitted to rise, so as to avoid undue formation of condensation products, which would be immediately seen in an increased flow of gas and a darkening of the crude liquor. This exothermic reaction, which also takes place in coal distillation, probably accounts for the increase in temperature of the uncondensed gases in the oven system, since no greater proportionate radiation takes place in this system than in that of the retort construction. At this particular stage, on account of the nature of the source of the heat (exothermic changes in the wood) a much more uniform temperature throughout the oven is maintained. This gives an excellent illustration of the possibility of considerable alteration even in the chemistry involved in a process when we change the mechanical manipulation.

An additional advantage obtained by this oven system is that the charge of residual charcoal may be drawn while the oven is still hot, thus economizing on the fuel necessary for reheating, while a partial cooling is necessary in the hand-drawn retort system.

The time lost during this cooling was saved in one design at Dahoga, Pa., where the retort at the conclusion of firing was removed by a crane from its vertical setting and replaced at once by a previously charged retort. It is stated in the meagre literature on this industry that "this type is probably most used."* This Dahoga installation, though it operated for many years, was the only plant that ever was installed in this country so far as we are aware, and certainly there is little likelyhood of any existing now, for this one was recently converted into an oven plant.

There is still a third system, which should be at least mentioned, namely, the kiln system. This was really the second in date of development, but the oven system was so closely allied in design and operation to the original retort system that the two were taken up together. The fact is, we would expect the logical development to have been: Charcoal heap—charcoal pit—charcoal kiln—by-product charcoal kiln—retorts—ovens, but this does not appear to have been the case, in this country at least. As in the coke industry we do not appear to have gone from bee-hive oven to by-product bee-

*MET. AND CHEM. ENG., 1910, p. 155.

hive oven, directly, but through the by-product oven, an outside and distinct invention, so in this industry charcoal kilns were only converted to the by-product kiln system after the development of the retort system.

When charcoal was produced in kilns, from 20 to 86 cords of wood were placed in a kiln constructed of bricks, and wood was used as fuel for carbonizing. The volatile products were lost through the opening provided at the top. With the advent of markets for alcohol and acetate some charcoal manufacturers placed a pipe connecting this opening with a suction fan and a condenser and thus collected the volatile products. The amount of product thus recovered is but a fraction of that recovered in a retort or oven system. In Pierce's system the flat-topped circular kilns usually hold 50 cords. They are heated by gas burned in a furnace under the kiln. For the sake of brevity, a description of these interesting kiln plants will be omitted since their recovery of by-products is low and they are confined almost exclusively to the blast furnace plants of Michigan, where they are steadily and rapidly being displaced by oven plants.

Yields

The low yield from the kiln system, which runs about 100 lb. of acetate of lime and 4 gal. of alcohol per cord, together with the low yields obtained by *rapid or quick* firing plainly show that there is a mean temperature

FIG. 4—A PENNSYLVANIA 66-CORD PLANT

which gives the maximum yield. Just what the curve of efficiency is, to our knowledge, has never been definitely determined in a commercial plant, though we have given it much experimental attention and others doubtless have worked on it also. In fact, there are so many factors to be considered in a comparison of experimental operations on a commercial scale that while the factors causing increased or lessened results are known, it is difficult to obtain accurate definite knowledge as to just how much each factor contributes to the results. For example, we know that Michigan plants under approximately the same construction and operation obtain less product per cord than those of New York and Pennsylvania without certain knowledge of the relative influence of the various contributing factors.

This lack of definite data on a commercial scale, so deplorable in most industries, results from the difficulty of obtaining successive tests with all conditions alike, for we well know that any variation, for instance, of temperature, has a peculiar relation to the results obtained. In addition it goes without saying that the variety or species of the wood enters largely into the

results obtained, and even the part of the tree used may cause variation. For example, a charge made up wholly of heart-wood will give better yields under the same conditions than a charge of slabs, making due allowance for the bark. Again we have found that weight for weight, cord-wood obtained from the mature or virgin trees will yield higher than the small second growth; also we are convinced of a noticeable difference in results from wood of the same species grown on high and dry places, and that from low or marshy soil, the latter giving a slightly lower yield. Indeed it is interesting to hear the experienced operator maintain that wood cut in the winter months will give better results than if cut while the sap is running. We are, however, unable to verify this expression, and it is possible that some other factor may have been responsible for this often-repeated statement. It is also held by many operators that eliminating the consideration of extra fuel necessary for the charring of green or unseasoned wood, the results are not the same in finished product as from well-seasoned wood. We can see from these statements that with so many factors to be considered, it is extremely difficult to determine which enter most into the discrepancies between the various systems; retort, oven, and kiln. However, from the purely practical standpoint we do know that there is a marked difference between yields obtained from the different systems as well as from the two general localities extensively operating.

FIG. 5—START OF OVEN PULLING

If we compare the results obtained by the same system operated in the Allegheny Mountains with that of the Lake Superior region, we find that by taking the results on a yearly basis from a well-operated plant and calculating the wood on a basis of a cord 8 in. by 4 in. by 52 in., there should be obtained conservatively 216 lb. of 80 per cent acetate of lime, 11.3 gal. of 82 per cent crude wood alcohol, and 52 bu. of charcoal. The yield from the Lake district is slightly under this in alcohol, and decidedly so in the acetate yield, which is 175 lb. to 180 lb. on continued operation. However, here again we have at least two factors and it is difficult to determine their relative influence. First, in the Eastern field, beech predominates, while in the other hard maple is in larger proportion, and also slab wood is used much more largely. In fact, we have been un-

able to obtain data from a continued operation in which at least a small proportion of slabs was not used.

Construction

At this point it may be well to take up the question of construction, especially of the most successful and modern system, that of the oven, which is, with the exception of the mechanical manipulation, similar to the retort system.

The ovens are of uniform height and width, in most plants being 6 ft. 3 in. wide and 8 ft. 4 in. high, the length determining the capacity, running from 26 ft. to 54 ft. and holding from 5 to 10 cords. The steel used in the shell is usually $\frac{3}{8}$ in., while the bottom and back heads are of $\frac{1}{2}$-in. material. Ovens are built either with doors at both ends in order to withdraw the residual charcoal coincidentally with refilling the oven with wood-loaded cars, or in many cases, with a door at one end, the oven being loaded after the charcoal has been run into the coolers. In any event the door is hung upon a cast-iron frame riveted on the oven. This frame has a groove of about 1 in. for the use of asbestos packing and the cast-iron door is hung to the frame by riveted cast-iron hinges. The oven is stiffened by means of angle irons riveted perpendicularly on the sides, and on one side near the top are riveted 30-in. cast-iron nozzles, usually two in number, to which are attached the condensers.

The first ovens installed were placed upon piers in the setting, upon which were iron plates and rollers to accommodate expansion of the oven, but in the later settings the ovens are suspended from tee rails laid across the brick setting at the top and supporting the oven by means of U-bolts riveted thereto. The bottom of the oven is equipped with clips for holding the rails which carry the wood cars. These cars vary but slightly in length in different plants, running from 10 ft. 4 in. to 12 ft. 4 in. inside length and about 78 in. high, thus each car holds from 2 to $2\frac{1}{2}$ cords of 52-in. wood. Each has four 18-in. wheels with roller bearings running on 2-7/16-in. turned steel axles.

Immediately in front of the ovens are two charcoal coolers arranged in series and approximately of the size of the ovens. Into the first the hot charcoal is drawn from the retort, where it stands for twenty-four hours. From this cooler it is drawn into the second one for another twenty-four hours of additional cooling. These coolers are made of very light iron with cast door frames riveted on each end, and light sheet-iron doors. No bottoms are required as the coolers are simply placed on the ground and banked along the sides and doors with loose dirt.

To the nozzles heretofore mentioned are connected the condensers. These are upright tubular condensers, made with copper hoods having a removable head and are bolted to gun-metal heads which are bored for the copper tubes, usually $1\frac{1}{4}$-in O. D. seamless copper, and expanded into these gun-metal heads, the whole surrounded by a steel water-jacket with water inlet at the bottom and outlet at the top. Connected to a bottom pan bolted on the lower head is a goose-neck trap for trapping off the non-condensible gases, thus separating them from the pyroligneous liquor, which is run into a wooden tank. The gas from the charge is carried into a main gas line which runs to the boilers where the gas is injected under them by a small steam jet. This jet performs the additional and very important function of serving to reduce any back pressure on the ovens, thereby preventing leaks. In order to prevent this suction from becoming too pronounced and drawing over the lighter volatile products through the condenser into the gas line, a butterfly or clapper valve is arranged on the line and regulated by a spring so set

that any undue suction opens the valve, thus relieving the line.

Primary Distillation Operation

After this general outline of the first stage of the construction let us follow the operation to this point. After the loaded cars are run into the ovens the doors are pinned shut with taper pins driven into lugs which are a part of the casting of the door frame. The fires are started under the ovens and in about an hour the water distillation and first dissociation begins, the distillate being of a very light yellow color and having a tannin-like odor, and running about $2\frac{1}{2}$ per cent of acid during the first hour when well-seasoned wood is used. Gradually this acid content rises until at about the fifteenth hour, when the content should be running from 12 to 14 per cent. After a few hours' running a small percentage of light tar begins to appear and steadily increases until at the latter end of the run tar is by far the larger constituent of the distillate. The acid content of the watery constituent gradually diminishes until it is almost negligible.

The product obtained under the usual practice, with average wood of at least a year's seasoning, is from 215 to 220 gal. of crude pyroligneous product giving an
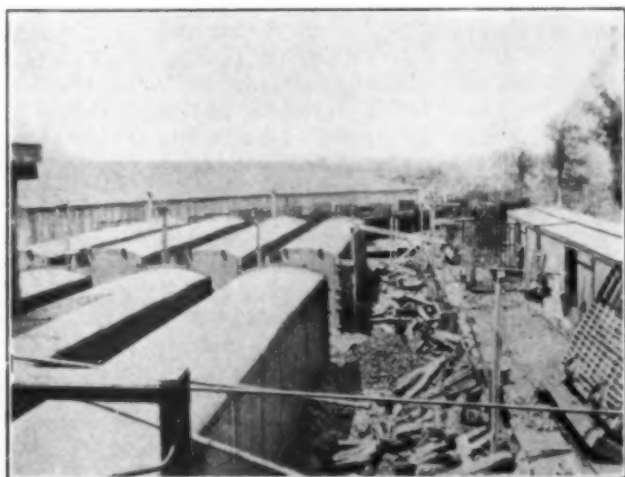

FIG. 6—CHARCOAL COOLERS. A NEW YORK PLANT

acid titration of 8 to $8\frac{1}{2}$ per cent and an alcohol content of 4 to $4\frac{1}{2}$ per cent. The tar yield is from 22 to 25 gal. to the cord, with a residual charcoal in the cars of about 52 bu. of 20 lb. each. With green or unseasoned wood the total distillate is diluted and will run from 275 to 325 gal. of liquid.

In the early stages of the run the non-condensible gases are largely air and carbon dioxide. Therefore for the first few hours, and even after much of the hydrocarbons and carbon monoxide are accumulating in the gases they have no fuel value. However, the percentage of carbon dioxide diminishes rapidly, and from the middle to the end of the run the oven gas has an important fuel value. The total amount of gas will run from 11,000 to 12,000 ft. per cord.

As we have already intimated, the influence of the temperature of dissociation is extremely important, and the yields are much dependent upon its regulation. For example, if during the height of the run the temperature at the neck of the oven materially exceeds 750 deg. Fahr. much greater volumes of non-condensible gases are being formed, together with an excessive amount of tar, and it is quite possible to lose from 5 to even 10 per cent of charcoal, together with a serious loss both of alcohol and acid content. Rapid firing, however, without reaching excessive limits will materially increase

the acid content at the expense of the alcohol, while slow, even firing, operating the oven at a period in excess of the usual twenty-four hours, will increase somewhat the alcohol production and lessen that of the acid.

The interesting results obtained from excessive firing arise, as we hope to show later, both from a difference in the chemical dissociation and also from the subsequent formation of condensation products.

In drawing the hot charcoal from the ovens, quantities of combustible gas remaining in the ovens would cause explosion on the opening of the doors. This is obviated by the introduction of live steam into the front of the oven for a short time before the drawing is made.

Handling the Crude Distillate

The crude distillate or pyroligneous acid, called in the works "raw liquor," is first pumped into a series of wooden settling tubs, connected with brass piping. The first tub, where the greatest amount of tar settles, is connected near its top with an overflow pipe to the second tub. The second tub is connected with the third by a pipe somewhat lower, and this series of drops is continued so that the last tub is drawn from within about 18 in. from the bottom. The raw liquor thus settled free from tar is, as a rule, continuously run into the copper stills. These copper stills are for the purpose of distilling off the lighter volatile products away from the tars and oils which remained in solution in the settled liquor. They are from 7 to 10 ft. in diameter with proportionate height, made of 12 to 14-gage cold-rolled copper, and equipped with a steam coil, usually of 3-in. or 4-in. seamless drawn copper tubing and starting from about 18 in. from the top and running helically around the walls and on the bottom to midway between the center and pheriphery. For a 2000-gal. still from 300 sq. ft. to 400 sq. ft. of heating surface should be used. In addition each still should be supplied with a live-steam jet applied at the bottom and preferably through a copper ring having small steam openings.

After a copper still has run continuously for some time it gradually becomes filled with deposited tar and its flow of distillate diminishes. When this has reached a stage of very slow production, as it does every four days, the feed valve is closed and the live steam jet is opened, distilling the tar with live steam, thus obtaining considerable quantities of acid and light oils. This latter distillate is run into separate tubs, where the light oil on the top is withdrawn before the acid liquor is pumped into the original copper still distillate which has been run into a wooden "mixing tub." The tar from the settling tubs is usually distilled in a separate tar still, sometimes made of wood, and distilled as has been that just described. This practice is followed as it permits the separation of the oils independently and without allowing them to come in contact with the original distillate, in which a portion would dissolve, thus the bulk of the distillate contains less impurities by this practice.

The mixing tub is usually from 12 to 14 ft. in diameter, and 4 ft. high, having a very heavy wooden stirring arm fastened to the end of a heavy shaft, operated by a slow moving gear at the top. Slacked lime is slowly added to the liquor in the tub, which contains its own indicator, the liquid changing at the neutral point to a pronounced wine color. For maximum yields, however, the addition of lime, probably owing to the acetic esters present, should be continued until this color has been followed by a yellowish one and until a bead appears or bubbles form on the surface and which disappear slowly. A very small further addition

of lime at this point causes the acetate to stick to the pans when evaporated and prevents satisfactory crystallization. Under-neutralization also causes inferior quality in crystallization, and before final drying the acetate has a decidedly black color instead of a rich yellow brown, and there is an accompanying loss in product owing to the esters lost.

From the mixing tub the neutralized liquor is jetted or run into an iron still known in practice as the "lime lee" still. In a few plants this is equipped with either Burcey pans, or in some more modern works with a fractionating column, although most plants do not fractionate at this point. The customary practice is simply ordinary distillation. The crude alcohol starts over at about 20 per cent on a Tralle scale, but quickly rises to 35 per cent and at times 40 per cent, gradually dropping in percentage to from 15 to 20, at which strength it continues for some time and then drops rapidly to 5 per cent or 6 per cent, at which point it seems to hold stationary again for a long period. After all of the alcohol has been distilled over, a valve in the vapor neck is closed and the residual acetate solution is blown, by means of live steam pressure applied in the still, to an iron settling pan above the top of the

FIG. 7—DUMPING CHARCOAL

ovens, where the excess lime and insoluble impurities settle out in a few hours. The acetate liquor is then drawn into flat steam pans having a jacketed bottom for steam supply, the pans usually being about 16 ft. long by 8 ft. wide and 18 in. deep. Here the acetate liquor is boiled rapidly until crystals appear on the surface near the edges, when the steam is reduced so that the crystalline film which forms at once on the top does not break, which would cause it to fall to the bottom and form a hard crust. Care must be exercised in this "seeding" process, as it is called, or a great quantity of this exceedingly hard crust or scale will be produced, which is unfit for the market. After this "seeding down" has continued until the whole mass in the pan has reached a very thick mushy consistency, it is shoveled out on the acetate or "kiln floor," which is a smooth brick or tile covered floor over the top of the ovens. Here the acetate is continually turned until dried and ready for sacking and shipment.

The "weak alcohol" from the "lime lee" still, containing from 9 to 12 per cent of acetone and alcohol, is accumulated and distilled in an iron still having either 5 or 6 Burcey pans or a column. This distillate is the final crude product produced by the works, and is usually shipped to a central refinery, although a few plants refine their own product. In this distillation all the product coming over above 60 per cent is run into the storage tank, and the lower fraction is put back

with the lime lee distillate for further distillation. The finished crude is sold on a basis of 82 per cent and contains about 16 per cent acetone.

Returning to the copper still residue, the tar from these stills, as well as that from the tar still, is run into a sump and from there jetted under the boilers for fuel. The two fuel products, gas and tar, furnish approximately 35 per cent or 40 per cent of the necessary fuel for all operations.

Before leaving this subject of operation it might be said that many of the earlier plants omitted this copper still distillation, neutralizing the raw liquor directly after settling and thereby obtaining the "brown acetate" of commerce, which is to-day practically without market. This brown acetate runs from 60 per cent to 65 per cent acetate.

Production Costs

The costs of producing the products above mentioned have been on a constantly increasing scale, owing in a large measure to the increasing cost of cord-wood and stumpage. During the past fifteen years in the eastern district, stumpage in suitable location has been sold for as low as 15 cents per cord, while to-day 75 cents to $1 is the approximate average. The cost of cutting varies from $1.15 to $1.35 per cord in fair timber, and in scattered timber $1.50 is sometimes paid. To-day, including transportation, piling, etc., this will make the cost on board oven cars $4 to $5 per cord, though wood is being put in for as low as $3.50 by users of mill-waste or by those having long standing holdings.

This gradual rise in the cost of wood is due to natural causes, among which are the increase in stumpage cost due to the ever-decreasing supply, and the natural rise in labor, together with increased length and cost of transportation. With the exception of one possibility, there appears to be no hope of any future lowering of costs. This one exception, a new cord-wood splitting machine, appears from our examination to have merit, and presents an entirely new system of cord-wood production. It is generally conceded that cutting and hauling the large log is less expensive than cutting and handling the cord-wood at the stump. The tree is therefore cut in logs and large limbs and transported to the machine, where a slide carries it first to a cross-cut saw, which cuts it into the proper lengths. The sawed pieces continue to a platform where they are either split in halves or quartered by one blow. The split wood automatically moves by a slide to the railroad car or wagon. It is claimed that under suitable conditions 50 cents per cord, or in some instances even more, may be thus saved. We have been unable to see continued operations of this machine as yet, and consequently cannot verify this saving cost, but are inclined to believe that at least some reduction in wood cost is possible by this means.

The cost of fuel for a crude works, in addition to the tar and gas used, of course varies with the available supply. In the New York and Pennsylvania districts,

TABLE I—PRODUCTION COSTS PER CORD OF WOOD	
Wood (maximum) per cord	$5.00
Fuel	1.15
Labor	1.25
Lime, 0.96 bu. at 19 cents	.18
Bags (acetate)	.14
Freight (acetate, 16 cents per 100)	.35
Freight (alcohol)	.10
Selling commission acetate	.11
Insurance, per cord	.068
Taxes, per cord	.112
General expense	.57
Total	$8.85

when coal is used, this cost will amount on an average to $1.15 per cord, and when natural gas at 15 cents per thousand feet is used the cost is but slightly more. The labor at the plant is usually counted at $1.25 per cord.

The summation of production costs given in Table I (p. 35) will be generally accepted as a fair basis in considering investment in new installations.

Production Values

With the present slump in markets the values herein set down are low, especially that for acetate of lime. The past 10-year-average would be about $2 per hundred, while at present the market is slow at $1.75 per hundred.

Alcohol (82 per cent), 11. gal. at 25 cents..$2.75
Acetate of lime, 216 lb. at $1.75............ 3.78
Charcoal, 52 bu. net at 6¼ cents.......... 3.38

Total crude value........................$9.91

This gives a production cost of $8.85 and a sales value of $9.91 per cord. It will be noted that no selling costs except in the case of acetate of lime have been included, because in the works not refining or making the finished products, which are in number far in excess of those who do refine, the alcohol is sold under contract to the refiner, and the charcoal is either, as in the case of those plants in the Lake district, consumer at iron furnaces in connection with the plants, or as in the eastern field handled by a general sales agency controlled by the manufacturers, proportionately to their daily production capacity, yielding to the producer about the above mentioned figure at present.

These production costs are based on the yields in the eastern field, which, as pointed out, were higher than those of the Lake region. This discrepancy is compensated however by the fuel wood costs being lower in the Lake region, owing to the fact that in most instances mill-waste is used. The general relation between the two fields of operation in this production cost and product value is therefore approximately the same. It is undoubtedly true that many manufacturers can show much greater net profit than the above figures indicate, because of cheaper wood and fuel, and in some instances because of plant design.

Costs of Installation

Eliminating the cost of wood supply, $2,000 per cord per day production is counted as a reasonable installation cost for a plant as described, for producing crude products. For instance, the cost of boilers, ovens, cars, coolers, pumps, etc., is substantially $650. Copper work, including stills, condensers, piping, etc., approximates $450. Brick work for ovens and boiler setting, etc., will come to about $190. These three general items are more or less about a fixed estimate, varying, of course, somewhat upon the price of materials at the time. The location, buildings and general costs vary with the design and the desire of the builder. However, the above stated general figure of $2,000 is a fairly accurate estimate, unless elaborate construction is undertaken.

Large Scale Experimentation

Realizing the possibilities and necessity of counterbalancing the increasing cost of production, several large operators have made extensive large scale experiments with a view of increasing yields and saving production costs. Unfortunately the results obtained thus far have not justified the expenditures made in spite of many optimistic claims (Met. and Chem. Eng., 1913, p. 434), owing in a measure to the many unlooked for complications which arise between the laboratory and the works scale. Of the great amount of work which has been done along this line with which we happen to be familiar, space permits the citation of but a few illustrative instances.

In the fall of 1908 certain men largely interested in the business went to Germany to investigate developments there and returned with a process for eliminating the copper stills and making gray acetate of lime directly from raw liquor, a proposal which had already been made and studied in this country. This process had been reputed to be in successful operation in Germany. It was in fact merely the application of the cup column to the neck of the ovens. The cups and openings were of course of larger size than in the customary column, but in effect this really was all that could be claimed for the new appliance. It was held that the pyroligneous vapors, passing through the condensed
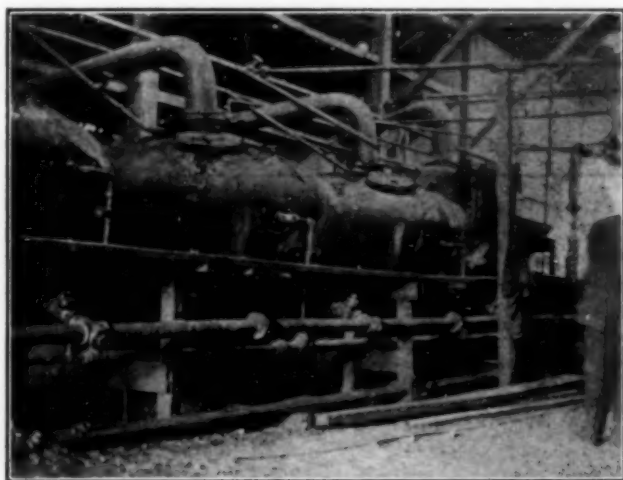
FIG. 8—ANCIENT TYPE OF COPPER STILLS, FORMERLY DIRECT FIRED, THEN CONVERTED TO STEAM HEATED BY A NOW DISMANTLED RETORT PLANT

tarry liquor, were freed from their impurities by this means and that gray acetate could be produced from the resulting raw liquor by direct neutralization. Educated or impressed by the then incomplete American investigations mentioned, these men permitted themselves to be carried away by the assurances of the German engineers and, as has happened several times in our industrial chemical development in more or less identical circumstances, without adequate experimental investigation they equipped a large plant with this apparatus at an enormous expense, the copper work for which alone exceeded $80,000. The plant did not prove satisfactory.

It will at once be seen from foregoing statements in this article, that there were two fundamental reasons which explain, in our opinion, the failure to obtain the desired results. First, as pointed out, mechanical clogging of the apparatus would occur, as was the case in the original worm condenser; and second, as we believe, the valuable products readily form condensation products with the unsaturated hydrocarbons and aldehydes present in the distillate. Certainly the passing of these vapors through the hot tarry liquid would tend to increase this chemical reaction. Moreover, the apparatus caused back pressure on the ovens and required a suction to overcome this objection. This increase of suction would tend to bring the vapors through the cups and the condensers at a more rapid rate, which of course would lessen their efficiency.

Later another process, also brought from Germany, was tried, which was in effect the same as the one

above described, except that the vapors were forced through a body of hot tar for the purpose of washing them, but this also was not successful. In our opinion this was for the same fundamental chemical reason as mentioned above.

A process for accomplishing this result, but not as yet entirely developed, from which some very satisfactory results have been obtained, is based upon a totally different theory from those mentioned. This method places a fractional condenser on the neck of the oven, which is maintained at a temperature sufficient to liquify the high boiling tars and oils. These, however, are largely mechanically carried along by the uncondensed and non-condensible gases, while a part of the tar is run off through a goose neck on the bottom of the fractional condenser, the uncondensed vapors and the non-condensible gases with their suspended tar and oil liquids are carried into the bottom of a centrifugal basket or drum, installed in a copper container and having small perforations inside of the drum, which is supplied with wings to give a rapid motion to the gases. This centrifugal action throws the liquid particles or mist against the side of the container, on which are deflectors set at an angle opposite to the
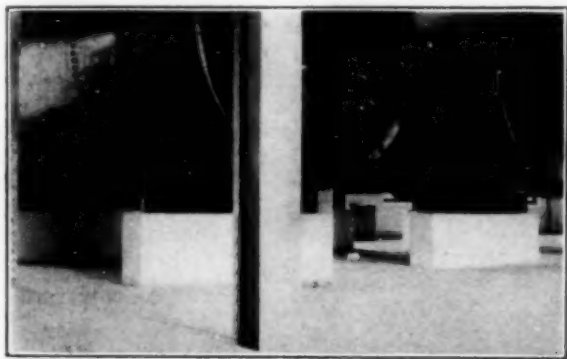

FIG. 9—SODA STILLS. WOOD ALCOHOL REFINERY

direction of the moving drum. Thus the condensed bodies are forced to the bottom of the container and out of the zone of circulation, through a goose neck into the tar receiver, while the vapors continue to a second condenser and are there condensed, the wood gas being trapped off in the usual manner.

This process has given uniformly increased yields of product, but exact data as to saving, yields and cost of operation have not been determined as yet. A little over one horsepower is necessary for the operation of a 7-cord machine until speed is attained, then three-fourths hp. is necessary.

The increase in product yield with this method is probably due to the fact that the vapor contact with the condensed and unsaturated bodies present is reduced to a minimum.

Another attempt at fuel conservation, which it seems should be possible of accomplishment, relates to the evaporation of the acetate liquor. As has been seen, much heat is necessary for evaporation of this liquor, and this method attempts to utilize the high temperatures of the gases at the oven's neck before they enter the condensers. We are not aware of any installation of this nature, although patents have been issued for accomplishing this end. Nevertheless, as it involves what appears to be a wholly mechanical manipulation there should be no great difficulty in saving at least a portion of this waste heat. Here again it can be seen that experimentation to accomplish this end is costly, since all experimental changes necessitate considerable financial outlay if tried on a large oven, and also involve

interruption of regular operation which must from time to time inevitably occur.

Under this head of experimentation may properly come an elaborate attempt to utilize hardwood sawdust for alcohol manufacture. This was undertaken in 1903 by a well known lumber company in Cincinnati, who endeavored to destructively distill sawdust continuously by means of an endless belt which carried the sawdust through an oven for the purpose of carbonizing, tapping off the pyroligneous vapors and obtaining an uninterrupted production of charcoal, which was briquetted. The distillate was handled in the usual manner.

It can be readily seen that sawdust can not be destructively distilled in bulk, as is cordwood, for the insulating space between the particles prevents the heat from going through the mass. This explains the reason for the endless belt.

No expense was spared either in buildings or equipment, the buildings being of stone and the equipment of the best; the whole costing probably $200,000. Notwithstanding this outlay the operation was a complete failure, the plant being dismantled within a year and the buildings used for other manufacture. The high fuel cost in attempting to overcome the resistance to radiation in such a mass was an important item in the high production cost which resulted in the failure. In addition, sawdust charcoal is a more dangerous fire risk than common charcoal, in the handling of which in the ordinary plant special arrangements are necessary.

Within the past five years some plants have installed double and triple effect evaporators with a view of fuel economy and reports as to the results are very contradictory, but the continued use indicates at least partial success. One Michigan plant is successfully drying its acetate with a drum and belt dryer. Vacuum drying for acetate has been tried, but we are unaware of any success, as the resultant product is a powder which the market demands the crystal.

Refining

From the time of the formation of the already mentioned Burcey Refining Company, the usual plan of manufacture contemplated only the production of the crude product as described, selling the product, those of the Eastern field, largely to a Buffalo refinery, and the Michigan manufacturers to Detroit, and up until the passage of the Denatured Alcohol bill by Congress they received a price usually ranging from 40 to 75 cents a gallon for the crude alcohol. After the passage of this act, and with the purchase of the Detroit plant by the one at Buffalo, the price of crude was at times as low as 15 cents per gallon, and during this period of adjustment intense depression prevailed amongst the crude producers, as it was feared that ethyl alcohol would largely supplant methyl. It was found, however, that the trade, particularly the paint trade, preferred wood alcohol even at a slightly higher price, and this fact virtually saved the industry. With the formation of a refining company among eastern crude operators representing somewhat over 1000 cords daily production, and the erection of a refinery at Olean, N. Y., the monopolistic control of refining was immediately reduced. A very acceptable dead rental was paid to the crude producers for their uncompleted refinery, as well as a substantial increase for their crude product, which eventually reached and is maintained at about 25 cents per gallon of 82 per cent product.

The method first employed by refiners was merely that of fractional distillation, and we all perhaps will remember the yellow, ill-smelling wood alcohol of commerce. Later, and for a long time, bleaching powder and sulphuric acid were used before the final distilla-

tion. This materially improved the product, but with the improvement of the columns used, treatment with sodium hydroxide and distillation is all that is necessary. The NaOH serves the purpose of polymerizing the aldehyde impurities. It also saponifies both the tarry matter and esters. The formerly objectionable acetone present, which distills with the heads, now has its own market value under the name of acetone-alcohol and is used in varnish removers, as a solvent in the rubber and other industries and also as a carrier for acetylene gas in lighting systems. Thus this 16 to 18 per cent of impurity is now in fact an added value to the refiner.

Markets

Prior to the present unfortunate European situation the average production of acetate of lime from the manufacturers in this country amounted approximately to 7000 tons monthly, and we are informed that the total European and Canadian production is almost equal to this, of which tonnage Austria-Hungary furnished about two thirds. The plants in Europe, however, are usually on a very small scale in comparison with those in this country. Sweden alone has plants of a size in

FIG. 10—ACETATE PANS AND KILN FLOOR

anyway comparable with the larger ones here. Of the production of acetate in this country, from 50 to 60 per cent is exported, a considerable percentage to or through Belgium. Of course, it will be understood that these statements refer to the market situation before it became demoralized by the European war, although for a year prior to the declaration of war there had been a pronounced stagnation of the markets both at home and abroad.

Of the acetate of lime consumed in this country, by far the largest percentage goes into acetic acid production. The hardwood industry is therefore vitally connected with this acetic acid industry, and one of the most important developments in the last decade is the successful beginning made in combining the crude manufacture and this refined or finished product manufactured in the same plant. Such combination plants have shown crude acetic acid yields in continuous operations running 92 to 96 per cent of theory, using 5 per cent sulphuric acid in excess of that theoretically required, and giving on a continued daily production of 4000 pounds, with a yield of 91 per cent of the possible theoretical yield, refined acetic acid of the finest double distilled quality.

The chief individual acetic acid market demands in this country are from the manufacture of white lead, paint colors, the textile and leather industries, although

in the aggregate the small consumers such as the laundries, ink and drug trades, consume great quantities. This country prohibits the manufacture of acetic acid vinegar, but its production is permitted abroad.

The consumption of export acetone produced in this country is chiefly by England, and Italy is just now a large consumer. The industry is in a particularly thriving condition at the present time owing to its use in production of explosives for the European war. There should be obtained 20 to 22 pounds of acetone per 100 pounds of acetate used, and in connection with the crude works acetone production is very profitable, as the general operating expenses are low. Of course its use in this country was very large for explosive manufacture and for the production of chloroform under the well known Rump patents, regarding which there was so much patent litigation some years ago and which as you know were upheld. In comparatively late years, however, a large Michigan concern has produced chloroform commercially from carbon tetrachlorid, which has probably influenced somewhat the acetate consumption for this manufacture. There are four plants in the United States producing acetone for the market and within the past week ground has been broken in Pennsylvania for a fifth plant. There is but one plant operating in Canada, to our knowledge.

Ten years ago the steel industry consumed by far the major percentage of charcoal produced. This percentage however has decreased considerably owing to the improved methods for steel production. Many industries such as cutlery and car wheel manufacture demanded charcoal iron, but in these and many other instances coke iron has been substituted. This falling off in the proportionate use of charcoal in iron production has been made up in an increased domestic demand. Charcoal is now sold in small paper sacks in many cities for use both in hotels and private families.

The production of crude wood alcohol amounts to between 10 and 11 million gallons per year, and of course it has innumerable uses, including that of the paint industry, which is the largest single user.

Space will not permit in a general article such as this, of going into details regarding production and markets of the other products such as formaldehyde, creosote, etc., which are directly or indirectly derived from hard wood distillation.

Distribution of Plants

Although not in agreement with any published figures, we place the distribution of distillation plants as follows:

Michigan.....	8 oven plants carbonizing...	1032	cords daily
	5 kiln plants carbonizing ...	1050	cords daily or
	13 plants carbonizing.........	2082	cords daily
Pennsylvania .	33 oven plants carbonizing...	1424	cords daily
	13 retort plants carbonizing...	215	cords daily or
	46 plants carbonizing.........	1639	cords daily
New York.. .	7 oven plants carbonizing .	256	cords daily
	17 retort plants carbonizing...	362	cords daily or
	24 plants carbonizing.........	618	cords daily
Wisconsin.....	2 oven plants carbonizing...	96	cords daily
	1 oven-kiln plant carbonizing	250	cords daily or
	3 plants carbonizing........	346	cords daily
Kentucky	1 oven plant carbonizing....	20	cords daily
West Virginia .	1 oven plant carbonizing ...	49	cords daily
Tennessee*....	1 oven plant carbonizing .	32	cords daily
Vermont......	1 retort plant carbonizing....	16	cords daily

This makes a daily capacity in this country of 2909 cords in 53 oven plants; 593 cords in 31 retort plants and 1300 cords in 6 kiln plants or a total of 4802 cords in 90 plants.

In Canada there are 9 oven plants charring 424 cords daily and one retort plant charring 48 cords, or a total of 472 cords in 10 plants. This makes a total for America of 5274 cords per day in 100 plants.

*A recently constructed 16-cord retort plant now being converted into an oven plant.

These figures will mean more to us if we remember that 5000 cords of wood represent a pile 4 ft. high and 52 in. wide and 7.5 miles long, weighing when seasoned approximately 10,000 tons.

These figures show the importance and size of the industry in this country.

Conclusion

It will be evident that the chief economic drawback in the present manufacture is the fact that most of the plants do not manufacture the finished products, thus in general it may be inferred that two sets of freight charges, commissions and handling expenses are required before the products reach the consumer. For instance, with acetate of lime at $2 the net return to the producer is about $1.75 per hundred.

A large part of this difference could easily be saved by undertaking the manufacture of the finished product at the crude plants.

Hitherto such combinations of crude and finished product manufacture have been thwarted in the majority of cases by an almost complete monopoly of the finished products by certain groups of chemical manufacturers, who by various manipulations maintained control of markets, or who were able to dominate the situation, as i nthe cases of asetic acid, by their regional control of sulphuric acid manufacture, or even attempted control of pyrites importation. The violent market fights which have developed because of these facts have
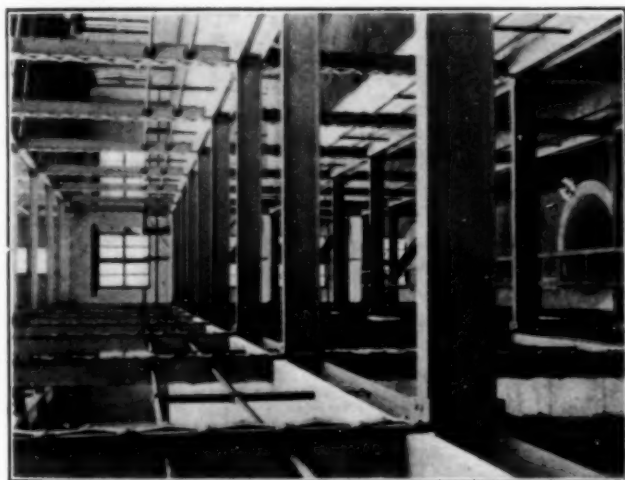

FIG. 11—THE COLUMN WALL IN WOOD ALCOHOL REFINERY

been carried through successfully in more than one instance by the crude manufacturer, because of his advantageous situation, and it is certain that these attempts, therefore, to thwart the natural economic development of this industry will sooner or later collapse to a great extent, or the refiner will be compelled to either go into the crude business himself or combine with the crude manufacturer.

We have attempted to show the difficulties met and the expensive experimentation that has been undertaken in the past for the improvement of this industry, and have pointed out some of the results thus obtained. When it is remembered that German statistics claim that but one of fifteen serious trials of new chemical processes are successful and that this percentage amply pays for the losses entailed in the fourteen unsuccessful ones, it can be seen that while these expenditures are individually unfortunate, in the aggregate this law of averages will probably hold good in the development of this industry for its economic position demands the solution of the problems indicated.

Columbus, Ohio.

The Natural Chill of Cast Iron and its Significance in the Manufacture of Malleable Castings

BY GRAFTON M. THRASHER

Some years ago the author of this article became impressed with the growing need for more light on the subject of iron mixtures generally. All published articles on this subject laid heavy stress upon the adjustment of the silicon with more or less vague statements as to what the proper percentage should be in various castings.

Many very arbitrary and conflicting statements were made by different writers and investigators which were very confusing to one in search of fundamental facts.

During the intervening years much has been done to clear up what were once great mysteries to the foundryman, but it seems that while we have collected an immense amount of data, yet very little of it has been coordinated in such a manner as to make it valuable to the foundryman; and the mixing of iron, while practically all done by chemical analysis at the present time, is largely done by formula or pattern mixture without a definite knowledge as to whether it is the best suited to the work or not.

Several years ago while the author was engaged as chief chemist for a prominent and long-established malleable iron company, it occurred to him that the mere regulation of silicon was not sufficient to produce the desired degree of chill.

While the author has often noticed this phenomenon before in connection with cupola iron it was only after being repeatedly impressed with it in the case of both, open-hearth and air-furnace metal that it occurred to him that variations in the total carbon was the principal cause of disturbance and after some thought on the matter it was decided to run total carbon as well as silicon on every heat and by a carefully prepared test piece to gauge the approximate degree of chill. The test piece selected for this purpose was a round plug cast in green sand on end and was 2 in. in diameter and 12 in. long. The plug was allowed to cool at least two hours in the mold before being cooled in water and broken in the middle, and the fractures were designated as grey, low mottled, mottled, high mottled and white. From the same ladle of iron from which the test piece was poured a shot sample was taken for analysis so as to represent the actual iron in the bar as near as possible and the test in all cases was poured from iron taken from the furnace when about half emptied.

It may be well to mention here that the principal disturbing influence on these tests is the fact (proven by experiment) that it is entirely possible to pour a mottled test and a grey test from the same ladle of iron, depending upon the pouring temperature.

In order to study the cause of the variations more systematically a chart was prepared for plotting the analyses with carbon as ordinates and silicon as abscissa. By following up this idea it soon became apparent that the analyses corresponding to the test piece with average chill designated as mottled were arranged along a diagonal line on the chart with analyses corresponding to high and low chill at a more or less definite distance on either side of the line. It so happened about that time that a heat had to be held pretty long in the furnace on account of a break down and it became necessary to doctor it up with 50 per cent ferrosilicon to get the metal into pouring condition. When this heat was out the test piece was examined and found to be just normal or what is designated above as mottled and the analysis corresponding was found to be silicon 1.07 per cent and carbon 2.47 per cent, which served admirably for one

extreme of the chill line as drawn on the chart. In casting about for something to form a point for the other extreme it was found in the shape of a pig of charcoal iron of the same dimensions as the test piece and with the proper degree of chill.

More recently the writer has obtained data for a new high-silicon point in which the analysis was, silicon 1.25, carbon 2.25.

The chart as finally constructed took the shape illustrated in Fig. 1.

As the manganese in all of these heats ranged be-

FIG. 1—LINES OF EQUAL NATURAL CHILL AND THEIR APPLICATION TO THE MANUFACTURE OF MALLEABLE CASTINGS

tween 0.25 and 0.35, which is normal for air furnace malleable and as sulphur averaged about 0.06 it will be seen that these elements interfered but little with the results. The phosphorus, of course, was between 0.13 and 0.18 and also had very little influence.

In examining the chart it will be noted that while the line tends to curve somewhat, yet it is sufficiently straight through the usual range of analyses so that for practical purposes we may assume that four (4) points of carbon are equivalent to three (3) points of silicon in the regulation of chill. When the silicon is above 0.70 per cent and below this about two (2) points carbon are equivalent to one (1) point silicon.

The value of this knowledge will be at once apparent to a malleable foundryman as it enables him to substitute large quantities of low-carbon material for his sprue in case of shortage of this material, thus:

It is desired to substitute steel containing silicon 0.10 and carbon 0.30 for 1000 lbs. of sprue containing silicon 0.80 and carbon 2.80.

> Equivalent deficiency of silicon in the steel due to low carbon equals 2.80 — .30 x ¾ x 1000 = 18.7 lbs.
> Silicon deficiency = .80 — .10 x 1000 = 7.0

Total equivalent silicon deficiency = 25.7

Therefore, it is necessary to increase the silicon in the mixture by 25.7 lbs. through substituting higher silicon pig iron.

The popular conception of malleable iron accepts the limits of 0.60 to 0.90 in silicon and with a very indefinite idea as to what the carbon content in the hard state should be, but a careful examination of this chart will show that for a given silicon percentage there is a definite carbon percentage which is proper for each class of castings.

In order to prevent cracked work and for other economic reasons the malleable foundryman runs his mixture as nearly grey as he dares, but if he desires to produce a very strong iron the presence of primary graphite in the hard iron must be avoided either by lowering the silicon or the carbon or both.

As to malleable iron produced with the same average chill but with varying analyses it will be found that the high-silicon, low-carbon mixture is more sound and reliable, but it is possibly a little less fluid, while the high-carbon, low-silicon mixture is subject to greater shrinkage and segregation which produce weakness.

The principal consideration for the foundryman is to produce that type of structure which is necessary to obtain malleability upon annealing and the chart shows the proper adjustment of silicon and carbon to bring about the desired results for the different grades of work.

It will be further noted that, of the three factors considered, namely, silicon, carbon and chill, if any two be known the other may be predicted approximately.

Malleable iron produced from the cupola is pretty well confined to the dotted circle shown on the chart, its proximity to grey iron as well as its position in the field of greater shrinkage will account for its weakness, which is not due as popularly supposed to the higher sulphur content. As the carbon is automatically adjusted within this range by melting in the cupola the regulation of chill must be effected by silicon alone. It is not feasible, however, to run a mixture which is lower than 0.50 silicon as the cutting action of the slag produced is very hard on cupola linings. Good malleable castings are being produced along the whole length of the charted lines, but the average foundryman with his limited knowledge of conditions to be met in another foundry cannot see how the other party makes a certain casting with 0.90 silicon while he finds it necessary to make it with 0.60 silicon. It is hoped that the publication of this chart will clarify the matter. The lines here given have been confirmed by plotting hundreds of analyses of mixtures of known chill and normal pouring temperature and the chart has been found a valuable aid in practical work.

The writer desires to acknowledge the inspiration received from an article by Prof. Henry M. Howe written several years ago, in which he urged practical men to take up the study of some data already collected and help interpret its significance. He also wishes to express his appreciation to his late employers, Stanley G. Flagg & Co., of Philadelphia, whose works probably afford better facilities for the study of this subject as applied to malleable castings than any other single plant in this country.

HASKELL & BARKER CAR CO.,
Michigan City, Indiana.

The Arizona Copper Co., Ltd., produced 1201 tons of copper in November, 1914.
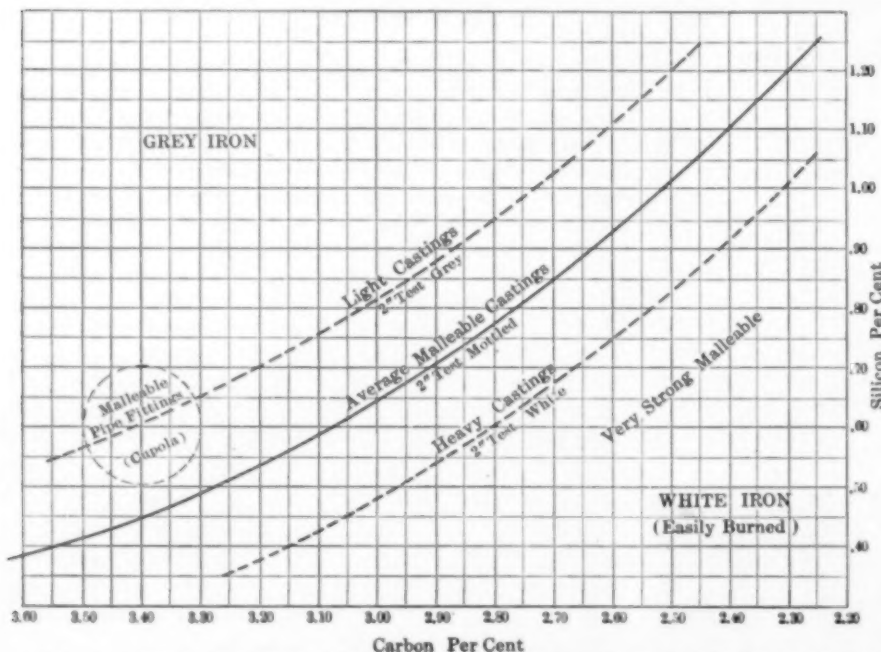
Philadelphia Meeting of American Institute of Chemical Engineers

The seventh annual meeting of the American Institute of Chemical Engineers was held in Philadelphia from Dec. 2 to 5.

The opening session of the meeting was held at Hotel Adelphia on December 2 at 10:30 a. m., president M. C. Whitaker of Columbia University presiding. The Institute was welcomed to Philadelphia by Mr. E. C. Cattell, representing Mayor Blankenburg, in an address fairly sparkling with wit and humor. The importance of Philadelphia as a manufacturing center was brought out forcibly by the speaker.

During the business session the result of the ballot for officers was announced. Dr. GEO. D. ROSENGARTEN of the Powers-Weightman-Rosengarten Co. was elected president for the coming year. Prof. J. M. Stillman of Leland Stanford University, Cal., was elected third vice-president. G. W. Thompson, chief chemist of the National Lead Company, and A. C. Langmuir, superintendent of the glycerine refinery of Marx & Rawolle, being first and second vice-presidents. The following officers were also elected: Prof. J. C. Olsen of Cooper Union, New York City, secretary; Dr. F. W. Frerichs of Herf & Frerichs, St. Louis, Mo., treasurer; Prof. A. W. Smith of Case School of Applied Science, Cleveland, O., auditor, and Mr. Geo. P. Adamson, Dr. J. B. F. Herreshoff of the General Chemical Company, and Dr. Samuel P. Sadtler, directors.

The secretary reported 228 members, a considerable gain over the last report. The treasurer reported a very satisfactory financial condition of the Institute, a deficit of long standing having been wiped out.

The Committee on Chemical Engineering Education reported that arrangements were being made with the Carnegie Foundation for the Advancement of Teaching for co-operation in their investigation of the present status of engineering education.

Prof. D. D. JACKSON of Columbia University read a paper on "The Manufacture and Application of the Artificial Zeolites (Permutite) in Water Softening," illustrated with lantern slides and samples of the products. The use of permutite for water softening was explained and a description of the process of manufacture given. Lantern slides giving views of the German as well as a factory in Brooklyn, N. Y., were shown.

Dr. A. S. CUSHMAN and Dr. GEO. W. COGGESHALL of the Institute of Industrial Research, Washington, D. C., presented the results of their investigations and experiments on the commercial extraction of potash from feldspar in a paper entitled "Feldspar as a Possible Source of American Potash." Several hundred tons of potash had been extracted from feldspar. Detailed estimates were given of the cost of a plant capable of handling 300 tons of feldspar daily, showing that potash can be produced from feldspar and sold at a profit. This paper will be published in full in our February issue.

On Wednesday afternoon the plant of the Atlantic Refining Company of the Standard Oil Company at Point Breeze on the Schuylkill River was visited. The method of distillation of the petroleum and especially the fractional condensation of the vapors and the method of control of the temperature of these condensers was examined with great interest.

The plant of the United Gas Improvement Company was also visited. The waste heat boilers were examined with great interest. The retorts are heated by a coke fire, which is fed by the hot coke from the retorts. The hot gases from the combustion of the coke after heating the retorts are carried through the tubes of the nearly vertical steam boilers. The gases enter the tubes at about 1200° F. and leave at about 350°.

On Wednesday evening at the Franklin Institute, Dr. GEO. O. SMITH, Director of the United States Geological Survey, delivered an address on the Distribution of Industrial Opportunities, showing the very widespread distribution of mineral and other natural resources in the United States.

Dr. JOKICHI TAKAMINE then delivered an address on the Chemical Industries of Japan, which include pottery, lacquer, cement, fertilizer, metallurgical and fermentation industries. By means of numerous lantern slides the old Japanese methods as well as modern up-to-date methods of manufacture were shown. A number of slides illustrating Japanese conditions of living were also shown.

GEORGE D. ROSENGARTEN,
PRESIDENT AMERICAN INSTITUTE
OF CHEMICAL ENGINEERS

On Thursday morning the plant of the Welsbach Works at Gloucester, N. J., was visited. The process of decomposing monazite sand with sulphuric acid, separating the thorium from the other metals and converting it into the nitrate was shown. The entire process of mantle manufacture was inspected, especial interest being shown in the solvent recovery plant where methyl alcohol, acetone and camphor were recovered and separated. The plating department was found to be very complete, nickel, brass and copper plating being shown as well as the production of a great variety of finishing coats and enameling. Brass casting and the manufacture of the metal parts of the lamps were inspected. After the visitors had been photographed a luncheon was served by the company.

During the afternoon a portion of the party visited the yards of the New York Shipbuilding Company, where several battleships are being built. The linoleum works of Farr & Bailey were also visited. The linseed oil was oxidized by blowing air into the oil and also by the older and slower method of exposing the oil to the air in a thin film on large canvas sheets. The oxidized oil was then melted with rosin and gum to produce the linoleum cement. The ground cork was mixed with the cement and coloring matter and applied to the burlap by means of steel rollers. The printing was carried out by means of flat plates, the various colors being applied successively and the finished linoleum suspended in long loops for drying. The manufacture of inlaid linoleums was also shown.

On Thursday evening a subscription dinner was held at Hotel Adelphia with about 50 in attendance. Past President Chas. F. McKenna acted as toastmaster.

Mr. Robert W. Leslie of Philadelphia, delivered a toast to the President of the United States. Mr. Cattell responded for the Mayor and delighted every one with his flow of humor and pathos.

Dr. Geo. D. Rosengarten, the new president, expressed his appreciataion of the honor conferred upon him.

Prof. J. P. Remington spoke of the many valuable services which Dr. Rosengarten had rendered for the advancement of the best interests of Philadelphia.

Prof. M. C. Whitaker urged the great importance

of greater frankness in the discussions of professional problems.

Toasts were also given by Prof. A. W. Smith, Mr. Wm. H. Bower, Dr. H. S. Miner and Prof. Wm. P. Mason.

On Friday morning a resolution was passed favoring San Francisco as the meeting place for the summer meeting of the Institute, the exact date to be fixed early in September by the Committee on Meetings.

A paper on "Hydrometallurgical Apparatus and Its Use in Chemical Engineering" by JOHN V. N. DORR was then read and illustrated by numerous lantern slides. The paper was a very interesting first-hand sketch of what the Dorr classifier, the Dorr thickener and the Dorr agitator have been able to do for the evolution of modern cyanide and general metallurgical practice. The application of the Dorr apparatus to analogous work in various chemical industries suggested itself. An interesting illustration of the increase in scale in modern metallurgical work in a Dorr classifier, 130 ft. in diameter and 6 ft. deep, of the Arizona Copper Company. The first part of this paper is published in full on page 55 of this issue.

Prof. JAMES R. WITHROW and E. H. FRENCH read a paper on the "Hardwood Distillation Industry," in which they presented the growth of this industry and the gradual evolution of methods and types of apparatus and showed numerous slides of typical installations. The paper, which is published in full elsewhere in this issue (p. 30) was discussed in considerable detail by H. C. Chute and others.

Dr. BERNHARD C. HESSE emphasized in a paper on "Need of Up-to-date Manufacturing Statistics" the great need of recent and reliable statistics of domestic and foreign manufacture and urged the appointment of a Committee of Chemical Engineers to cooperate with similar committees of other technical societies in assisting the United States Department of Commerce in this work and especially calling attention to the needs of the chemical profession in this respect.

Friday afternoon the Commercial Museum was visited, where Dr. Wm. P. Wilson explained the work of the museum. The laboratories of the University of Pennsylvania were then inspected, the members of the Institute being received by Dr. Edgar F. Smith, Provost of the University. Members were very much interested in the old English chemical balance which had been used by Priestley.

Friday evening Mr. G. W. THOMPSON read a paper on "Causes of Paint Defects," in which he showed that many defects such as checking, cracking, peeling, etc., are due to faulty methods of application and not to any inherent defects of the paint materials. He showed that the yellowing of white paint is caused by alkalis and especially by traces of ammonia in the atmosphere. The paper was illustrated by lantern slides.

Mr. H. A. HUSTON of the German Kali Works, explained the methods in use in the German potash mines by means of delightful moving pictures. He also explained the methods in use for refining the crude ore.

Dr. EDWARD GUDEMAN, in a paper on "Aspects of Some Chemical Industries in the United States To-day," showed that it is entirely feasible to manufacture in the United States many of the chemicals needed at present.

On Saturday morning a large delegation visited the chemical department of the Barrett Manufacturing Company at Frankford, Philadelphia, Pa. At this plant the light and middle oils obtained by the distillation of coal tar are used for the preparation of naphthalene and carbolic acid. The oils are first fractioned by distillation and condensation in a column still. The naphthalene is allowed to crystallize out and separated by means of a centrifugal. The crude naphthalene is melted, al-

lowed to crystallize and again separated by means of a centrifugal. It is then treated with sulphuric acid and distilled and the product sublimed. By means of a similar process pure carbolic acid is obtained. Various oils used for disinfecting purposes are also produced as by-products.

About 100 were in attendance at the meeting, which was very successful in every respect.

Dr. John C. Olsen, Cooper Union, New York City, is the secretary of the Institute.

Colorado School of Mines Short Course for Prospectors

To promote the more efficient prospecting of the mineral lands of Colorado, the Colorado School of Mines will establish a short course for prospectors, to be given at Golden, beginning February 8, 1915, and continuing for three weeks.

The work will include both lectures and laboratory studies involving the simple and ready tests for the detection of minerals in the field, as well as a consideration of geological formations favorable for various mineral occurrences.

No fees will be charged for this course other than a nominal charge to cover the cost of supplies used, which should not exceed $3.00.

The course is open to prospectors and others interested in the more intelligent prospecting of our mineral areas.

Electrical Energy Exported from Canada

Of the hydro-electric energy generated along the international boundary in Canada more is exported to the United States than is used in Canada, according to a report issued by the Dominion government. The total production of electrical energy in 1913 by Canadian companies with transmission lines extending into the United States was 1,543,464,097 kw-hrs., of which 772,-597,049 kw-hrs. were exported and 770,867,048 kw-hrs. were used in Canada. The totals by companies are shown in the accompanying table:

KILOWATT-HOURS OF HYDRO-ELECTRICAL ENERGY EXPORTED FROM CANADA OR USED IN CANADA

	Exported from Canada	Used in Canada
Canadian Niagara Power Co.	400,214,908	1,1420,020
Ontario Power Co.	282,123,004	412,597,896
Electric Development Co.	42,154,000	191,885,670
Western Canada Power Co.	23,213,891	39,339,239
Ontario & Minnesota Power Co.	21,649,327	868,856

In addition a large amount of hydro-electric energy is generated by Canadian companies in the vicinity of Montreal, Toronto, Quebec and Winnipeg. This is not included in these figures, as none of it is exported.

Resolutions relating to copper as contraband of war were adopted by the American Mining Congress at its recent session at Phoenix, Ariz., appealing to the United States government "to use its great offices to keep open every available market for copper and give full protection to the producers of the metal in the shipment of same in neutral vessels to neutral ports."

An echo of the war is found in the statement that the South African School of Mines has been closed owing to the departure of students to join various units of the defence force. Those who have not been called have been employed by the Consolidated Gold Fields group of mines.

The Rand and the War.—From the *South African Mining Journal* we learn that the president of the Chamber of Mines feels that the position of the mining industry with regard to the war is satisfactory. "Ample supplies of cyanide, zinc and mercury seem assured, and further shipments are now coming forward." Prominent operators express the opinion that the gold industry in South Africa will not suffer.

Handling Iron and Cinder at the Blast Furnace

BY J. E. JOHNSON, JR.

In the early days of the blast furnace it was probably the custom to allow the iron to run out in puddles in front of the furnace and there cool, but soon this crude practice developed into making a runner leading away from the furnace and putting short lateral runners off from one side of it so as to mould the iron into convenient shape for future handling. The runner was rather crudely formed as were the lateral runners, which also were few in number.

The general appearance of the whole arrangement was roughly similar to that of a sow with a litter of suckling pigs, from that comes the name of pig iron, and to this day the runner from which the individual "pigs" are cast is known as the "sow."

In still later times as outputs grew the pigs were not cast directly from the main central runner, but this branched into lateral runners at right angles to its course, and from these, at right angles again and therefore parallel to the main runner, ran the individual pigs. The combination of the branch runner or sow and the pigs which go with it are known as a "bed."

This system of casting the iron persisted as practically the only method of handling it until very recent years. Even at the time of the "Duquesne Revolution" when nearly everything else about the furnace was improved almost past recognition, the handling of the iron was changed only in detail rather than in principle.

Casting in Sand Beds

The runner and beds were until about twenty years ago practically always made up in sand, since sand does not wash in a liquid with a high surface tension like a molten metal, and at the same time is porous enough to permit the gases generated by the action of the intense heat of the iron on the water and organic matter it contains to escape freely. This is a matter of the utmost importance because if such free escape through the sand is not permitted the gases generated will bubble up through the liquid metal when their pressure has risen above that corresponding to the depth of metal upon them, and when this pressure is reached the action is very rapid, because the head decreases as the gas rises, while the volume of the gas simultaneously increases, as it bubbles up through the metal.

The consequence of these ebullitions is that the sand is disturbed when the gas is released, and the hot iron is given access to wetter and fresher sand underneath, with consequent generation of more gases, and its release in turn with a still greater tendency toward violence. This action continues progressively, if it once gets started, until a "boil" results.

These are spectacles of impressive beauty, like magnificent fireworks, for those not concerned in their results, but are frightfully expensive, not only in the loss of iron, but in the difficulty of removing that which remains in the center after the boil is over.

The depth to which one of these boils will dig in a short time is almost beyond belief, and if one occurs close to the front of the furnace so that there is no room to deflect the iron above it, it constitutes one of the worst interruptions that can befall the operation of the furnace.

I have seen a mass almost wholly of iron, but with a little cinder on top, about the shape of a huge strawberry, six feet in height mend more in diameter, taken out after a boil of only a few minutes duration, at the end of the iron trough. The difficulty of digging down to the bottom of such a boil and draining the liquid iron from the bottom of it is enormous, and a delay of hours in the operation of the furnace is practically certain to occur as a result of such a catastrophe in this location. For this reason the quality of the sand used in the pig beds, and particularly in the runner, is of vast importance. It must be coarse and open-grained, practically free from clay, and also free from lime, oxide of iron or any similar material which can unite with the silica at the high temperature of the iron and form a slag, and if such a slag be formed it will cause great waste of sand, dirty iron and a tendency to boils by sealing the pores of the sand beneath.

The first great change chronologically from this established method of handling the iron was the introduction of the mixer, of which, however, it will be more convenient to treat later.

Casting in Chills

Next to this came a change forced by the introduction of the basic open hearth process for the manufacture of steel. In this all silica introduced into the open-hearth furnace has to be slagged with lime of something like twice its own amount, which it is very likely to size from the bottom of the furnace, and so cause rapid wear of the latter as well as heavy expense in the consumption of lime.

For this process, therefore, some substitute for sand casting was found to be almost a necessity; this was found in the use of chill molds. These are virtually pig beds of cast iron which replace the ordinary sand beds and are fed from the central sand runner, the same as the original sand bed. These chills are not a modern invention. I have seen one which was made and presumably used at a charcoal furnace before the Civil War, but real need for sandless pig iron did not develop until the early nineties, consequently the chills, which are somewhat troublesome until the details of handling them are learned, never came into general use until then.

Certain irons, particularly hot irons, low in silicon, and made on a very limy furnace have the power of attacking and dissolving cold cast iron and burning to it. Obviously if this action took place to any extent the pigs would burn fast in the chills, and it would be impossible to remove them. To prevent this the molds are grouted with a solution of clay water soon after the removal of the cast from them, their heat then dries the water and leaves a coating of clay all over the chill. This is virtually infusible and serves to protect the chill from the action of the iron unless the latter is of an unusually cutting nature, when it sometimes burns fast to the chill in spite of the clay. Sometimes lime is used in place of clay, but clay is more easily held in suspension in water than lime, and is, therefore, more easy to apply uniformly.

These chills are exposed to enormous stresses. The whole bed of iron is obviously the same size as that of the chill at the instant of solidification, but as the iron cools off the chill absorbs its heat so that one gets hotter and the other colder. In order to get the cast out quickly it is customary to water it down with several hose nozzles as soon as the iron has solidified, and this of course throws still greater stresses upon the chills, but if the molds in the chill which form the pigs are of the proper shape and properly reinforced, they stand up very well under this treatment. It is necessary to have a considerable thickness of metal below the bottom of the pig, six inches is a minimum and eight is considered better. The bars between the pigs are known as the "cores," and including these the average thickness of the chill is from nine to twelve inches. The width of the chill in the direction of the length of the pig is over four feet and its length may be anything dictated by the size of the cast house and local conditions, but beds eighteen or twenty feet long are not uncommon.

A brief calculation will show that these must be very

heavy and in fact they weigh many tons. In some cases the beds are cast in several pieces, two or three, as this reduces the contraction strains and increases their durability, it also makes the individual pieces much easier to handle, although it is more troublesome to keep them in line with one another when made this way, unless longitudinal bolts are provided for holding them together.

Breaking the Iron

Each bed of iron when cast is obviously in the form of a huge comb and to render it merchantable this comb requires to be broken apart, and almost universally in foundry work the individual pigs require to be broken in two, this labor was in earlier days performed exclusively by hand. There are two ways of breaking, hot and cold. The former takes the least labor but is the hottest and the most disagreeable. It consists in catching the iron at the temperature immediately below solidification when it still has very little strength, and breaking the pig from the sow by the use of a crowbar applied under the junction of the two. The men wear clogs with wooden soles an inch thick, kept soaked in water when not in use, which are strapped to their shoes. A good deal of dust arises from the disturbance of the sand, while the radiation from the pig beds is very great in spite of the fact that a thin layer of sand is sprinkled over them, which cuts the heat down very greatly.

In the South where the conditions of atmospheric heat and humidity are relatively bad the custom has arisen of allowing the men to break the iron cold. The beds are watered down as soon as they are cooled below the point where sudden chilling will effect the fracture and appearance of the iron, the men then go on the beds with heavy sledges and crowbars and break the iron from the sow and break the individual pigs in two. This requires more labor and so is more expensive, but the work is more endurable for the men.

When the iron is cast in chills it is watered down and as soon as it has solidified the men work on it in pairs. One takes a short crowbar in each hand and pries up the point of the pig where its contraction has shortened it up so as to leave a gap of about half an inch between it and the chill. This man puts a heavy upward strain on this point with his hand bars, while his partner strikes a hard blow at the junction of the pig and the sow with an extra heavy sledge. This breaks the pig off from the sow and the latter is pried up and broken into two or three pieces by sledging after the pigs are all broken from it.

Casting the iron into chills instead of casting it in sand exercises a profound influence on its structure, particularly with irons low in silicon such as are required for the basic open hearth process and for which chills are used. If the iron be 1 per cent or over in silicon its fracture will be markedly different, when cast in chills, from that produced by casting in sand; it is much closer and finer grained, but the general nature of the iron is not much affected. But when the silicon gets down below 0.8 per cent, particularly if the sulphur be above 0.5 per cent, the iron begins to chill, and if the silicon drops still further it becomes perfectly white, very hard and excessively brittle. This is an advantage for steel making purposes since it has been proven that chilled iron melts more easily than the same iron not chilled, and therefore this facilitates melting down the iron in the open hearth furnace.

But for general foundry work casting in chills has only been introduced very slowly and after much missionary work among foundrymen who have very largely learned to judge the iron by its fracture and general appearance, an iron of open grain with large crystals being in general much superior from the foundryman's point of view to a close-grained iron with small crystals for general work. Therefore casting in chills converted good iron into bad from the foundryman's point of view, and if the silicon was a trifle low converted a really useful iron into one which foundrymen would not consent to use under any circumstances because it was "white."

This condition is gradually wearing away as foundrymen come to use analysis instead of fracture to judge the condition of their iron, but many merchant furnaces supplying the foundry trade still continue, and will for years to come, to cast their iron in sand.

The labor involved in these operations is generally not excessive measured in foot pounds of work performed, but must be done in a relatively short time to permit the cast house to be cleared for the next cast, therefore the men have to do the work under high pressure and under excessively disagreeable conditions owing to the heat and dust.

Pig Breaker

In order to overcome these hindrances to continuous and inexpensive operation the Duquesne furnaces were provided with chill beds, but they were also provided
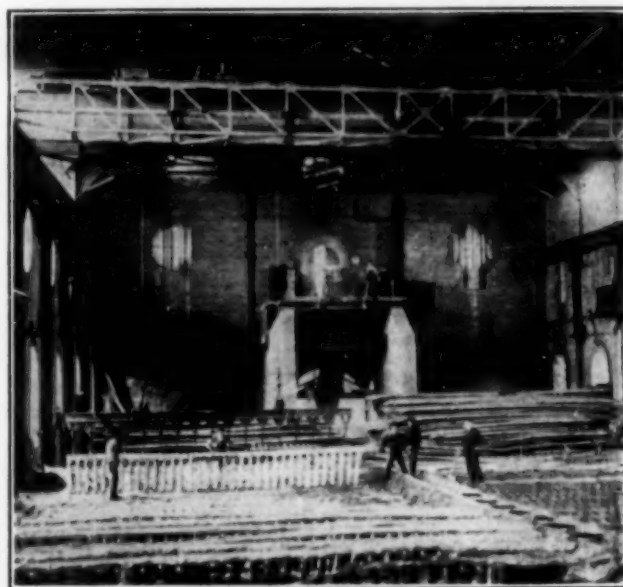
FIG. 1—INTERIOR OF CAST HOUSE WITH PILE OF PIG BEDS. CRANE LIFTING ONE PIG BED OUT OF SAND

with a crane in the cast house and the individual pigs were made vastly larger, both of heavier cross section and much longer than the ordinary pig, and were picked up by the crane which carried them to what was probably the first mechanical pig breaker. There they were laid down upon a table of rollers which fed them up to a hydraulic plunger working up and down which broke them into short sections.

Since that time the introduction of the crane in the cast house has become more general and should be universal. It is not only an enormous saving of labor in handling the iron, as I shall presently show, but is a convenience of incalculable value in times of breakouts, boils, putting in and taking out iron troughs, and assisting in the operation generally.

Since the time of the Duquesne Revolution the pig breaker has been much more highly developed, and in modern plants where pig beds are still used the handling of the iron is reduced to a mechanical operation.

The Brown Hoisting Machinery Company of Cleveland have developed the pig breaker in most common use, and through their courtesy I am able to show in Figs. 1, 2, 3, 4 and 5 the whole operation of handling the iron. In Fig. 1 there will be seen suspended from

the crane an I-beam carrying a number of heavy steel hooks. These hooks are lowered down over the bed and a couple of them are hooked under the sow and raise it onto blocks as shown in Fig. 2, in which position a fresh hold is taken of it with practically all the hooks engaged, the whole comb constituting a bed of two or three tons weight, may either be taken directly to the breaker in the rear or piled up as shown to the left of the breaker at the rear of the cast house. This is of particular convenience in case it is desired to have the analysis of the whole cast before breaking the iron and delivering it into the cars.

Fig. 2 shows the pig bed hanging from the hooks with its end entering the jaws of the breaker. It will be noted that the breaker is set at a high level, and in the center between the two piers on which it rests may be seen a chute leading out of the arch doorway at the rear. Into this chute the pigs drop as they are broken and slide into the car which takes them to their destination. The iron therefore is practically never touched by hand in any way until it comes to be unloaded at its destination, and while that is no part of our present concern,
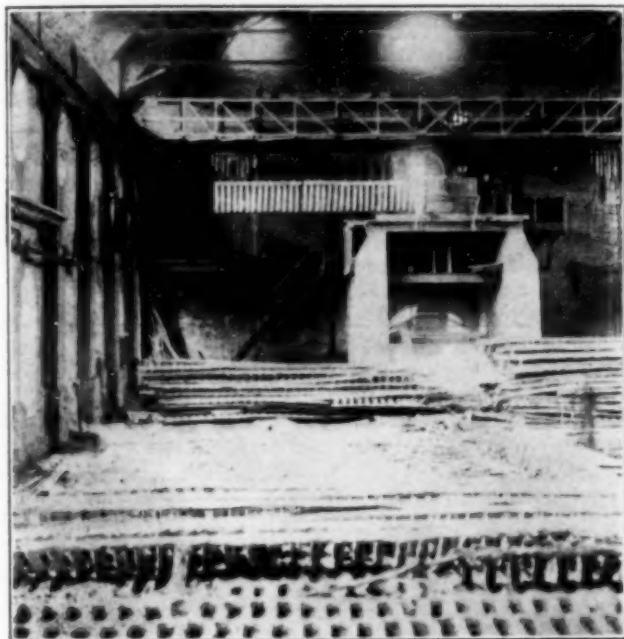

FIG. 2—INTERIOR OF CAST HOUSE WITH PILE OF PIG BEDS, ONE HANGING FROM CRANE

it is not amiss to say that that operation is now very generally carried on by huge magnets operated by cranes, so that even there no hand labor is required.

Figs. 3, 4 and 5 show the pig breaker itself. The vertical column at the left carries two horizontal plungers, one above the other, operated by hydraulic pressure. The column at the right acts merely as an anvil. In operation the comb is fed between the jaws by the crane; the first plunger is driven out against the top of the pig just where it joins the sow, and forces this over firmly against the anvil. The lower plunger is then forced out against the projecting bottom end of the pig, which it breaks off across the horizontal fulcrum seen about midway of the height of the anvil. This breaks the pig in two. The sow being supported by its top edge, with the bottom edge unsupported, while the end of the remaining portion of the pig is supported on the fulcrum, more pressure is then thrown on the top plunger, which is opposite the unsupported bottom edge, and this additional pressure breaks the pig loose from the sow, the sow is then broken into suitable lengths by

proper manipulation of the position of the comb and of the pig breaker itself.

The hole in the floor just to the right of the operator delivers the pig into the top of the chute shown in Fig. 2. There is one of these on each side of the machine, so that no matter on which side the pig falls it reaches the same destination.

A pig machine has also been brought out by Mr.
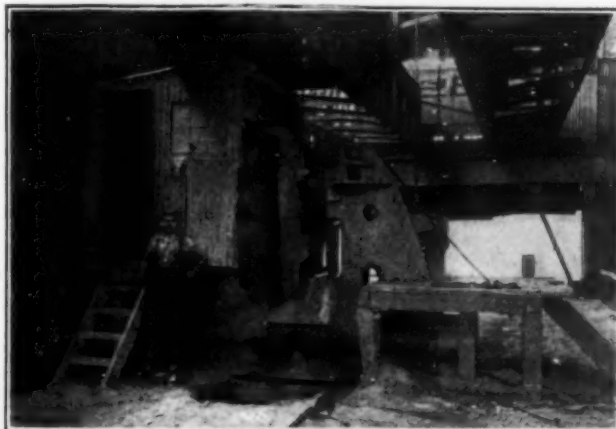
FIG. 3—SIDE VIEW OF PIG BREAKER

James B. Ladd of Philadelphia, but the principle of this machine, while somewhat different from that of the Brown, is not so radically different as to require separate illustration.

The amount of labor saved by the introduction of this equipment is enormous. When it is realized that 500 tons is considered the normal output of a standard size furnace in the Lake Ore district, and that under the old regime this would have required to be broken by hand, then carried piece by piece and thrown onto trucks, by them carried from the cast house to the railroad car, and then thrown from the trucks to the railroad car, it will be seen that the labor involved was
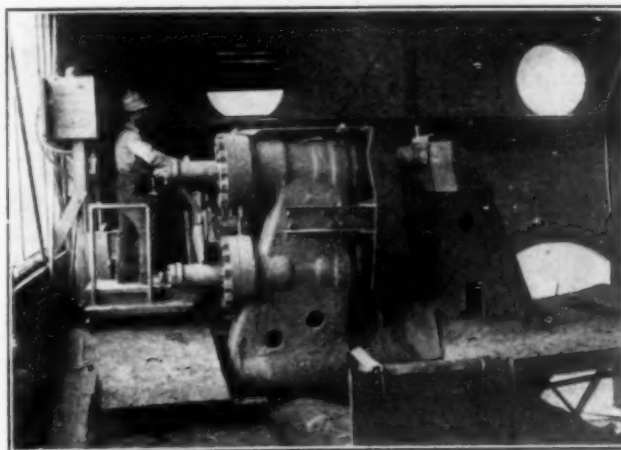
FIG. 4—PIG BREAKER, SHOWING HYDRAULIC CYLINDER AND ANVIL

tremendous and of the heaviest and most undesirable kind. Such labor is increasingly difficult to secure, and to handle, and the introduction of methods of handling pig iron by machinery is almost a necessity where it must continue to be cast in sand.

Molding Up Sand Beds

The beds were formerly molded exclusively by hand and still are in many cases. The sand is leveled off in the cast house floor, there is a pattern for the sow

and one for each pig, which are set down on the level surface thus prepared, the sand removed from the bed to level it is thrown back between the pigs and tramped to place to pack it, then struck off the top of the pig patterns, which are made with a considerable taper, these are then drawn by hand and thrown to the place for the next bed below, followed by the sow pattern.

This is probably the most laborious of any operation of considerable degree left around the blast furnace, and no means have been found as yet to reduce it to a very great extent, although where there is a crane in the cast house the pattern for the whole bed is made up in

FIG. 5—PART OF PIG BED OR COMB IN JAW OF PIG BREAKER

one piece and handled by the crane; this saves a certain amount of manual labor, but so small a proportion of the total that the practice has been abandoned for the use of the old single patterns in some cases.

Various attempts have been made to reduce this labor but the sand has to be cut up with shovels after each cast has been watered down, not only in order to set in the pigs, but also because it is too much compacted by the wetting to provide the necessary free vent for the gases. This, with the necessity of having the beds nearly level with just enough fall to the sows and the pigs to cause the iron to run into them without overrunning the far ends, has made conditions too difficult to be met by machinery sufficiently simple and robust to perform the service in other particulars.

It seems not improbable now that the increasing use of the casting machine will eliminate sand casting entirely before mechanical methods are developed for molding the pig beds.

Handling Liquid Pig Iron

In the early days of the Bessemer Process, the first applied to the manufacture of steel on a great scale, it was customary to cast the iron at the blast furnace as described, take it to the steel works, melt it down into cupolas and then take it to the converters for conversion into steel. This was done so that an opportunity might be provided to analyze the iron and to make the mixture in the cupola suitable for use in the converters. This practice involved an enormous waste in two ways, first the labor of casting the iron into pigs as described above, and the disposal of the pigs; second, the labor and fuel required for remelting this in the cupola. This was accompanied by a very objectionable increase in sulphur from the coke used in remelting.

Many metallurgists sought to eliminate this double loss by using the metal direct, but furnace practice was not as regular and uniform in that day as it is now, and there was no certainty that the iron produced at one cast would be suitable for the converters because the last cast had been, and if the variation in composition were great the converter practice was completely upset.

The late Captain W. R. Jones, of the Edgar Thompson Works, solved the difficulty by the invention of the "mixer," a huge steel vessel lined with fire brick, mounted on trunnions and tipped back and forth for pouring by a hydraulic cylinder. The first of these had a capacity of 150 or 200 tons of iron, but later ones have capacities up to 600 and 800 tons.

All the iron from all the furnaces is poured into this mixer and that for all the converters is drawn from it. This provides a "cushion" to absorb the fluctuations in the quality of the metal and secures gradual variations of the metal delivered to the converter, which enables the converting mill to adapt itself to these changes without difficulty, while of course the mere fact of mixing the output of three or four furnaces necessarily reduces the average variation at least to one-third or one-fourth of that for any individual furnace, and generally much more.

Thus the mixer exercises two good influences. It greatly reduces the absolute size of the variations, and it makes them gradual instead of sudden. This improvement permitted the use of direct metal at the steel works, and practically all modern plants of combined blast furnaces and steel works operate on this system. Where steel is made by the basic open hearth process as well as by the Bessemer, a separate mixer is used for this iron, and the same advantages are secured in that practice.

The use of "hot metal," as it is universally called, for the steel works involved the necessity of having ladle cars to transport it from the blast furnace to the mixer and thence to steel works. These started out
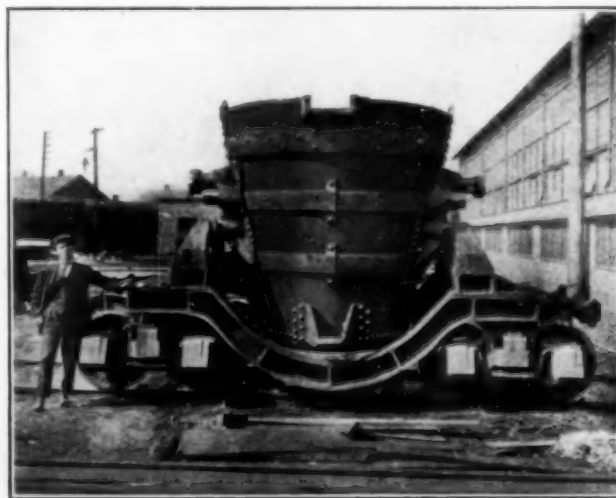
FIG. 6—POLLOCK HOT-METAL CAR

quite small, ten or fifteen tons capacity, but have gradually grown with the increased use of hot metal until 45, 50 and 60-ton ladles are now considered standard.

A ladle capable of carrying this amount of molten iron sometimes for distances of several miles, with entire safety from breakage of the apparatus or liability to accidental tipping, and yet capable of being easily poured where desired, is an apparatus of no mean proportions.

Such a ladle built by the William B. Pollock Company

is shown by Fig. 6. It will be noticed that this ladle is provided with five trunnions, two pairs below and a single one above on each side. It is also provided with a spout on each side and with a pocket for a hook at the bottom immediately under the spout to provide a convenient hold for the tilting mechanism. The single trunnions above are used in carrying the ladle on cranes; the two lower sets are used for pouring from the frame of the ladle car itself. The ladle revolves during the early part of the tilting movement around the forward one of the bottom pair of trunnions, but if it continued to revolve about this until empty its spout would be very low, necessitating a heavy drop for the metal poured at first in order to make room for the spout in its low position.

The purpose of the upper pair of trunnions with the corresponding jaws on the ladle truck shown beneath them is to prevent this low drop of the ladle spout, and it is obvious that when these upper trunnions reach a seat in the corresponding jaws on the truck the ladle revolves around them, the lower pair leaving their seats. This obviously throws the spout up much higher at the conclusion of the pouring operation. By this means the drop from the spout of the ladle is reduced several feet over what it formerly was, which is an advantage wherever it is used, but particularly in connection with casting machines to be described presently, of which the receiving end with the old style ladle had to be placed below the track, but with the style here shown,
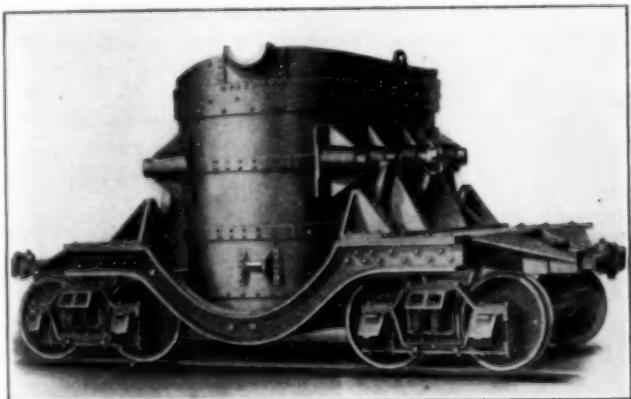

FIG. 7—TREADWELL HOT-METAL CAR

on account of the high position of the spout at the end of the pour, these machines can be raised above the track with the result of making them much more accessible and less expensive to install.

A hot metal ladle built by the Treadwell Engineering Company is shown by Fig. 7.

Casting Machines

The increase of furnace outputs during the nineties, of which I have spoken, required very large cast houses to take care of the iron, and the labor involved in breaking and carrying out these huge quantities of iron by hand was, as I have already explained, frightful. The entire plant depended upon iron carriers, since the furnace could not be operated unless the iron were carried out not *some* time but within a very limited period, so as to permit the beds to be made ready for the next cast. These conditions had the result of making this class of labor extremely hard to handle.

Conditions in this respect were, in one way, made worse by the growing use of hot metal at the steel plants, because it was necessary to have the iron carriers for Sundays and for emergencies when the steel works could not take the iron, while these men were not

needed the rest of the time. This brought a demand for a mechanical means of taking care of the iron from the furnace. Casting machines had been in use at a much earlier period for copper, lead, etc., on a small scale, and under rather easy conditions, owing to the fact that the temperatures of those metals are far below the melting point of iron, so that iron molds could be used without great difficulty. But the case was quite otherwise with the blast furnace; the only material of

FIG. 8—HOT-METAL LADLE IN POURING CHAIN, POURING INTO BRANCHING TROUGH FILLING MOLDS

construction available was iron or steel, and the iron cast into either of these was likely to burn fast to them if they were not thoroughly protected, while if the metal was poured into them while wet violent explosions would result.

Various engineers attacked this problem, but the credit for the first successful solution belongs to E. A. Uehling, who designed a machine consisting of two endless chains in tandem. The first carries molds for the pigs into which the iron is cast, it is chilled by passing under a heavy spray of water on its course, then discharges at the terminal sheave onto the second chain, a conveyor of slats running for some distance under water, which cools the iron down to a temperature low enough to do no harm, this conveyor in turn discharg-
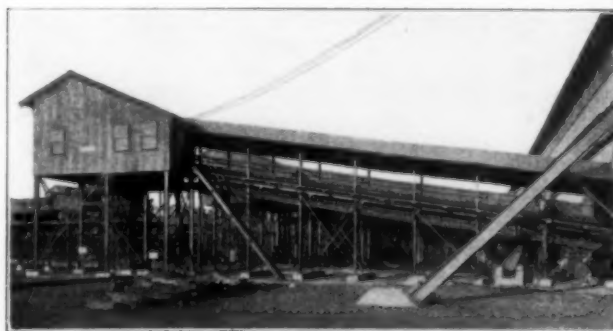
FIG. 9—FIRST OR CASTING CHAIN OF GROUP OF UEHLING MACHINES

ing onto the railroad cars which take the iron to its final destination.

Through the courtesy of the Heyl & Paterson Company I am able to show drawings, and an excellent set of photographs, of one of the largest installments of these machines ever built. Fig. 8 shows the ladle in a tipping chair which is elevated by the jib crane shown at the right and pours into a trough at right angles to the track, which branches both ways at its far end, each

branch pouring onto a separate strand of the pig machine.

Fig. 9 shows a general view of the ascending chain of the machine with the returning buckets on the under side.

Fig. 10 shows clearly a general view of the machines, the head houses where the casting chains discharge onto the cooling conveyors, the terminal houses from which
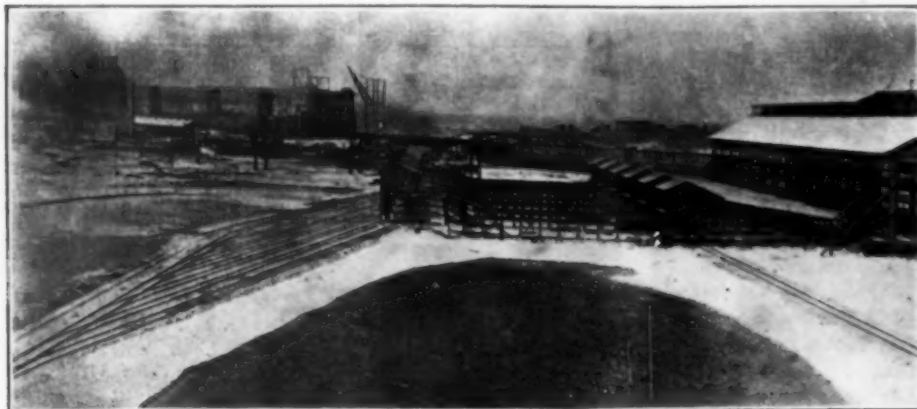
FIG. 10—GROUP OF UEHLING TYPE MACHINES

the latter discharge into the cars, and the excellent ladder arrangement of tracks for serving the machines without the necessity of switching the cars under all of them to reach any desired car.

A view of the cooling conveyors with their water trough and the return side of the chain below is shown in Fig. 11.

The difficulty of having the metal burn onto the molds

FIG. 11—COOLING CONVEYORS FOR UEHLING TYPE OF
MACHINE. WATER TROUGHS EMPTY

is obviated by having a jet of lime water from a tank underneath the return chain thoroughly sprayed up into the buckets as they pass over it on their return trip. The heat remaining in the mold causes the lime water to dry on it in a heavy white film, which of course is extremely refractory and prevents the contact of metal to metal, without which burning fast does not occur.

Another type of machine was brought out about the same time in which the functions of both chains are merged into one. This was the design of the Heyl & Paterson Company, who now build both the Uehling type of apparatus and their own.

In this apparatus one chain performs both functions. The metal is cast into it at one end, it then passes down a slight grade into a long tank standing full of water where the iron is thoroughly cooled, rises out of this

tank at a sharp elevation and is discharged over the end sheaves directly into railroad cars.

A photograph of an installation of this type is shown at Fig. 12, also by the courtesy of the Heyl & Paterson Company. Unfortunately the machine was empty at the time the picture was taken, but the molds show so clearly, also the way in which they pass under the water and out again and the overflow for keeping the water at the proper level that their action is perfectly obvious. A photograph of the same apparatus before the water was turned into the tank is shown in Fig. 13. The molds used in this conveyor are of steel, formed in a hydraulic press out of a piece of plate. They are subjected to terrific strains with the hot metal on one side of them and the cold water on the other, and after a certain amount of this service they lose their shape but can be repressed and restored to useful condition several times before they break from this treatment.

In some cases cast iron molds are used instead of steel. These of course fail by cracking and not by bending and are not capable of any further use after such failure. On the other hand they can be melted up and recast direct from the furnace in the floor of the cast house with very small expense, whereas when the steel molds once fail the loss is greater.

Both styles of molds have their advocates and both continue to be used after a number of years experience, so that the question of whether it pays better to

FIG. 12—HEYL & PATERSON TYPE OF CASTING MACHINE,
STEEL MOLD SINGLE CHAIN, TROUGH FILLED
WITH WATER

use one kind or the other is probably very largely a local question.

The merchant blast furnace isolated from steel works will probably prefer the cast iron molds which it can produce from its own metal with a small amount of labor, while the steel works making steel plate and having available machinery for pressing the molds may find it cheaper to use the steel.

The introduction of casting machines of one type or

the other has become practically universal at blast furnaces directly connected with steel works, and even at many merchant furnaces. The huge cast house which was one of the prominent features of the blast furnace of former times has disappeared at such plants and nothing is left of it except a building large enough to cover the troughs in which the iron is run to the spouts above the ladles and to serve as a protection

FIG. 13—HEYL & PATTERSON TYPE OF CASTING MACHINE, STEEL MOLD, SINGLE CHAIN

against the weather around the base of the furnace itself.

Iron Troughs and Skimmers

A few feet of iron runner next the tapping hole has been used for many years, for the reason that if properly grouted and dried it is reasonably free from the danger of having the iron burn fast to it on one hand, and on the other entirely prevents unexpected moisture or other causes from producing a boil close to the tapping hole, because while a violent explosion is caused by molten iron running onto even the smallest wet spot on anything made of iron, it is prevented by the iron from burrowing deeper after each explosion, as it does when a boil starts in the sand.

A bad boil immediately at the tapping hole would prevent the shutting of the latter, and would put the furnace out of commission for an almost indefinite time and would constitute a catastrophe, therefore the iron trough is used to prevent this at all hazards.

Up to within a few years the runners from this point on were entirely of sand and the necessary arrangements for skimming the cinder from the iron were also built up of sand. The cinder has a specific gravity only about one-fourth to one-third that of the iron, and while the two come out of the tapping hole together during the latter part of the cast the cinder immediately rises to the surface and can be skimmed off without difficulty. To accomplish this the portion of the runner next to the iron trough is made very large relative to the portion below this point and a dam of sand some five or

six inches high is put into the bottom of it four to eight feet from the iron trough; just above or in front of this is set a skimmer, formerly a thick plate of iron cast in open sand in the floor of the cast house, and guided by two pairs of pins driven into the sand of the runner on each side of it. When the cinder begins to show on the iron this skimmer is driven down with a hammer until its edge projects below the surface of the metal sufficiently to prevent the head of cinder floating on the iron from pushing under it, the cinder then rises and flows over a lateral dam, a low place in the side of the sand trough, and is led from there to its point of ultimate disposition.

With large and rapid streams of iron which were the consequence of the growing outputs of the nineties, this operation became more difficult and less certain. Either cinder was allowed to get down onto the iron, which created a fearful nuisance as the cinder broke off when the iron was cold and fouled the pig beds, or the iron itself would be forced out over the cinder dam and wasted. Moreover there was left in the basin formed by the iron and cinder dams at the end of the cast a considerable volume of iron with a heavy layer of cinder on top of it. To direct this iron to its proper place and keep the cinder from following it was by no means an easy matter, and much iron was likely to be lost in the cinder without the most careful practice.

In order to overcome these difficulties Mr. Michael Killeen at the Edgar Thompson works devised the Killeen skimmer. This consists of an additional section of iron trough linked to the section next the furnace. It has cast with it the cinder and iron dams, a slot in which to set the skimmer (preferably made of firebrick in an iron frame to prevent its cutting away during the cast, as the old iron skimmers did), and a supplementary lateral outlet extending clear to the bottom of the trough and closed by an iron gate with a loop in the top. Before cast this gate is set to place and the point between it and the body of the skimmer trough well protected with sand and grout. With this arrangement the skimmer can project far enough below the surface of
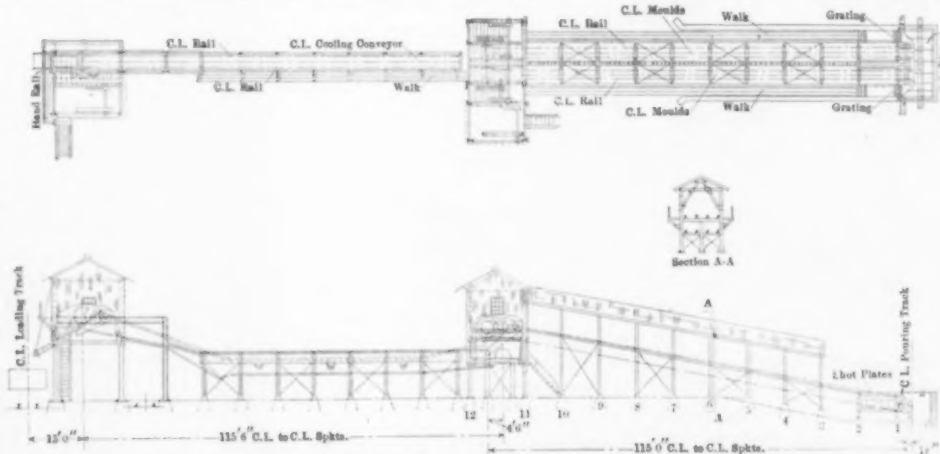
FIG. 14—GENERAL ARRANGEMENT OF UEHLING CASTING MACHINE

the iron to prevent the possibility of cinder getting down the iron runner, while at the same time the cinder dam can be raised so high as to prevent the iron from rising over it and running to waste. The considerable volume of iron remaining in the trough at the end of the cast is released by withdrawing the supplementary lateral gate and allowing the iron to run into a special runner which takes it either into a ladle or to a special bed set below the level of the other beds as may be preferred. The cinder is prevented from following it by a hand gate dropped when the iron is all discharged and before much of the cinder can follow. This not

only prevents the iron from being wasted and the cinder from getting down the iron runner, but also drains the iron trough effectively to the bottom so that easy access is thereby afforded to the tapping hole in order to stop it.

Other forms of skimmers have since been brought out, but are only variations of the general principle of the Killeen design.

Following the introduction of the iron skimming trough iron runners were substituted for the sand runner all over the cast house. These are provided with grooves into which gates are set to cut off the flow of the metal, and are grouted after each cast with a mixture of sand and clay kept hot by a steam coil, the gate grooves being filled up flush with this mixture. With good practice only a very light skull of iron is left in

these iron runners when the cast is over, and the runner requires only a new coating of sand and grout to make it ready for use again.

On account of its smoothness and uniformly sloping bottom the iron runner drains itself better than the sand runner, which prevents the formation of any but light scrap; moreover, with the iron runner it is possible to raise a gate which has once been set and allow iron to flow again down a section of trough from which it had been cut off, which it is never safe to do with sand runners because the withdrawal of the gate from the sand is extremely likely to cast a boil. These advantages have resulted in the universal introduction of iron runners where the iron is run direct to the ladles and not cast in sand beds.

(To be concluded in February Issue.)

Chemistry and Lighting

The New York Section of the American Electrochemical Society opened the season by a session at the Chemists' Club on the evening of November 10, devoted to a symposium of papers on contributions of chemistry to illuminating engineering. The meeting was held in co-operation with the American Illuminating Engineer-

COLIN G. FINK, CHAIRMAN NEW YORK SECTION AMERICAN ELECTROCHEMICAL SOCIETY

ing Society and the American Gas Institute. The chairman of the New York Section of the American Electrochemical Society, Dr. Colin G. Fink, of the Edison Lamp Works of the General Electric Company at Harrison, N. J., presided.

Introductory Remarks of Chairman

Dr. Colin G. Fink, in his introductory remarks, said that in the development of new and better forms of illumination chemistry has played a most important part. "For many decades the element carbon has been the basis of the best illuminants, whereas to-day we find investigations proceeding in three distinct lines: rare earths, rare metals, and rare gases. Professor Nernst and Baron Auer von Welsbach are among the most noted exponents of the rare earth investigations which have led to the Nernst glower and the modern incandescent gas mantle. Few of us realize that the modern electric

arcs embody chemical problems which are only partially solved.

"And yet the very best and most efficient forms of lighting of to-day realize but 6 per cent of the energy, 94 per cent being lost as heat. The very best minds in America and abroad are striving and seeking to produce a light as economical as that of the firefly, whose little 'lamp' 'burns' at an efficiency of 98 per cent."

Chemistry of the Incandescent Gas Mantle

Dr. **H. S. Miner,** chief chemist of the Welsbach Light Co., Gloucester City, N. J., presented the following paper:

In responding to the invitation to tell you some of the new developments in the chemistry of the incandescent gas mantle, I very much fear that my hearers will be doomed to disappointment if I am expected to describe some startling change that has taken place in that industry. Since the wonderful and spectacular invention of the brilliant Austrian chemist, Dr. Karl Auer von Welsbach, who about thirty years ago produced the incandescent gas mantle which in all justice bears his name, the growth of the industry has been marked by steady improvements rather than revolutionary changes, unless indeed we are to include that radical change in the composition of the mantle body which Dr. Auer himself made, when in the early nineties he substituted the thorium-cerium mixture for the more complex lanthanum-zirconium-cerium mantle which had comprised his first commercial mantle body. This was indeed a radical improvement, and it marked the beginning of the general adoption of the incandescent gas mantle.

I have said that the days of *radical* developments seem to be in the past, and yet I never cease to wonder at the phenomenon of the change or petrifaction of the vegetable or organic fiber, reproducing the cellulose fibre in mineral form under the influence of the Bunsen flame and giving the light-producing body with which we are familiar. And although we hear the fragility of the mantle frequently alluded to, yet when I watch its formation in this manner, which seems to be essential to its light-giving efficiency, the strength and resiliency of the mantle is a "nine days' wonder" to me.

This change in the composition of the Welsbach mantle when the mixture of 99 parts of thoria and 1 part of ceria was substituted for the earlier mixture, has ever been to my mind an invention of the highest type, involving as it did the purification of rare earth materials beyond the limits of previous knowledge, and then the development of commercial processes for the

production of these rare earths in the highest state of purity.

Notwithstanding the extravagant claims made by many *pseudo* inventors, the thorium-cerium mixture still holds as the essential composition of all Welsbach mantles, and this, and this alone, is the basis of the light-giving qualities of the incandescent gas mantle; although the last quarter of a century has brought us much enlightenment upon the field of rare-earth chemistry, no satisfactory substitute has been found for this early invention of Dr. Auer's. An intimate knowledge of this industry from the very days of its infancy leaves me with an ever-increasing respect for the work of the pioneer, Dr. Auer.

In justice to the faithful and meritorious work of the many rare-earth chemists throughout the world, I would say that their work has resulted in certain changes and improvements in the mantle and burner which have decreased its cost and increased its efficiency and durability. Some of these points I will endeavor to touch upon.

In the early days a purified cotton fabric was saturated with the thorium-cerium mixture made of materials of as high a state of purity as possible. The purity of the cellulose was found to be absolutely essential, and the well-known bleaching and washing processes were carried beyond the point previously thought to be necessary, and a cotton carrying less mineral substance than the best absorbent cotton was soon produced. Realizing the deleterious influence of foreign substances, such as silica, lime, magnesia, alumina, phosphoric acid, etc., it was recognized that it was just as harmful to have these elements brought to the mantle from the vegetable fibre as from the rare-earth mixture.

It was early recognized that the length of the fiber or staple of the mantle fabric had much to do with its physical strength and its durability. Long staple cottons were used exclusively in the best grade of goods, and the longer fibered ramie or China grass was looked upon with favor when it was first introduced, but it was not used with any success by mantle manufacturers until it had been successfully de-gummed, bleached and washed. The accomplishment of this complex and difficult problem resulted in the adoption of ramie as a mantle fiber first in Germany and then in other countries. The adoption of ramie fiber made possible the mantle of the inverted or pendant type, which has since been so generally adopted.

Although the staple of the fiber had been increased in length from $1\frac{1}{2}$ or $1\frac{3}{4}$ inches to 5 or 6 inches by the substitution of ramie for Sea Island cotton, and that with certain advantages, especially in inverted mantles, yet the ideal had not been reached, and it remained for the artificial silk or artificial cellulose fibers to supply that ideal. The delay in the development of the artificial silk industry caused a delay in the adoption of artificial fibers as a mantle-making body, but its many striking qualities of strength, elasticity and maintained candle-power have caused a persistence of effort that now had its reward in the arti-fiber mantle.

In the early days the only digressions from the ideal composition of 99 per cent ThO, to 1 per cent CeO, were slight variations in these figures within narrow ranges to produce lights with varying degrees of whiteness, an increase or decrease of ceria increasing or decreasing the yellow color of the light produced. The coming of ramie fiber and the inverted type of mantle made the introduction of small percentages of hardening materials essential, and beryllium oxide was found to be an ideal substance for this purpose.

The change of fiber and of the type of the mantles as indicated has caused a complete revolution in the processes of manufacture, and notwithstanding the experience already gained, each one of these changes has called forth a line of research that had made persistent work over a period of years essential before the problem could be considered solved. This is especially true of the arti-fiber mantles, and the changes in manufacturing processes have extended to the collodion or lacquer used to strengthen the mantle for transportation, for the collodion used on the cotton or ramie mantles was found to be entirely unsuited for arti-fiber mantles.

The problem of primary importance for the chemical engineer, as related to this industry, has ever been the manufacture of thorium nitrate, and many changes in the commercial production of this substance have, of course, been effected during the score of years just past. Monazite sand has always been, and still is, the only commercial ore from which thoria could be obtained, and contains from 5 to 6 per cent ThO,; although small deposits of thorite and thorianite with a thoria content of 50 per cent and 75 per cent respectively have served to keep alive within us an appreciation of, and longing for, a more ideal ore as a source of supply. The high price of monazite—this very low-grade ore from a thoria standpoint, with nearly 95 per cent waste—has thrown upon the thoria content, while still locked up in this phosphate rock, a heavy burden of expense and has made necessary the production of high yields and low costs of operation to keep the cost of thorium salts low enough to make them commercially available.

The first processes used in factory practice were naturally but enlargements of the well-known laboratory methods of analysis, while from this beginning have developed modification after modification, substituting cheaper and cheaper reagents and methods of manipulation until the commercial processes of to-day hardly bear even a "family resemblance" to the first process employed. These modifications are, of course, still continuing, and are made imperative by the fluctuation in price either of the ore, of some reagent, or of the price of labor. But although there be variations in processes, there must be one unvarying standard ever before the chemist in charge and all of his associates, and that is the absolute purity of the product. Pure thoria is vitally essential, and I am gratified to be able to say for the thoria manufacturers of the world that their product is of very high grade and is better now, notwithstanding the cheapening and shortening of processes, than it was in the beginning, although even then it was sincerely labeled "C. P."

There are various means, both chemical and physical, of checking and determining the purity of the product, but in the light of experience the most satisfactory method for both accuracy and rapidity is the manufacture of mantles from the thoria as it progresses in purity. The color of the mantle body, the color of the light produced, the presence or absence of shrinkage, the brittleness or flexibility of the mantle give to the experienced manufacturer a more satisfactory indication of the purity of the product than do the chemical analyses, which are of necessity long and tedious.

The other essential material which must always accompany thoria is ceria, and although it is used in only about one one-hundredth the quantity as thoria, yet its chemistry is just as important and its purity just as essential. I am glad to say that this product is even purer than when Dr. Auer first used it even in larger proportions in his lathanum-zirconium-cerium mantle. The oxide of cerium then obtained was of a reddish-brown tint, while that now manufactured is of a light yellow color, the former product having been slightly contaminated with neodymium, the last traces of which were difficult to remove.

By way of variety, and in order to add zest to the

work of the mantle chemist, he has also to manufacture beryllium, zirconium and neodymium, each of which he uses in a limited way, and none of these substances are really easy to produce.

Radio-chemistry has recently thrown the thoria manufacturer into the "lime-light" because of a radio-active product three hundred times stronger than radium, which occurs in and is produced from the thorium which he manufactures. I refer especially to meso-thorium, which a suffering and stricken humanity has implored the thoria manufacturers of the world to save for them, and which these manufacturers are now unitedly conserving as a substitute at least for radium.

With the possible exception of the meso-thorium just alluded to, every problem we have mentioned has a bearing upon the characteristics and qualities of some or all types of incandescent gas mantles. There is another and no less important problem, however, that should be alluded to, and that is the protective coating that must be applied to a finished mantle to strengthen it temporarily for transportation. In the early part of 1888 we were dipping the finished mantle in an alcoholic solution of shellac, made slightly flexible upon drying by the addition of a little castor oil. Some essayed to strengthen the mantle by the use of paraffine, and I have in my collection of curios a mantle imbedded in a cake of paraffine, which was to be removed by the melting away of the paraffine wax.

The invention of solutions of nitro-cellulose or soluble cotton opened up a new field of research, and the knowledge gained of the many various forms of nitro-cellulose and the numerous solvents therefor, together with the knowledge and control of such characteristics as viscosity, hydroscopic effects, etc., have made it now possible to prepare collodion solutions of almost ideal qualities for mantle purposes.

And what are these ideals? A collodion must be of the proper viscosity for mantles to be dipped in and withdrawn from it without rupture or strain; it must dry quickly with a film stiff enough for the mantle to be handled with safety, and yet strong and elastic enough to resist handling and shock; it must burn off slowly enough to prevent the mantle from becoming annealed or softened, and yet it must not leave the mantle body sticking to the cap of the burner. A collodion which answers these ideal characteristics is now realized in a nitrocellulose solution in a mixture of solvents with camphor made flexible chiefly by the use of castor oil.

I said in the beginning that the type of spectacular developments in the incandescent mantle industry were apparently over. At the close of this very general review I am, however, strongly tempted to modify this statement, and to class the commercial development of the arti-fiber or artificial silk mantle in this class of achievements.

The mantle manufacturer has held before himself for a quarter of a century and more certain ideals towards which he has earnestly striven. Some of these have been strength with elasticity, high and maintained candle-power, preservation of color and absence of shrinkage. A realization of these ideals seems finally to have been met in the mantle made from the bundle of elastic, spring-like fibers known as artificial silk, for the strength of these mantles certainly is something phenomenal, the high initial candle-power is not only maintained, but is frequently *increased*. This is made possible by the practical absence of shrinkage upon prolonged burning and by the very curious phenomen that this mantle does not seem to collect the fine mineral dust from the atmosphere as do those manufactured from the shorter vegetable fibers, cotton and ramie, this silicious dust having a very great affinity for the basic materials of the mantle body.

The attainment of this ideal has been reached only after years of persistent research guided by many more years of experience in mantle manufacture. Old theories had to be abandoned and former methods completely changed before this mantle was commercially possible. This was a chemical problem of great complexity, and its successful solution arouses such enthusiasm within me that I am tempted to include this among the radical and spectacular developments in our industry.

I have described some of the chemical problems connected with the manufacture of the incandescent gas mantle. There are many more that have to deal with the detailed process of manufacture of the mantle itself and with the economics of the industry, such as the conservation and recovery of waste products, but I will not weary you with a highly specialized paper. My chief excuse for treating the subject as I have done is to make it clear that each new type of mantle that is developed is an independent chemical problem from the beginning with the fiber of which it is formed, through every process and stage of manufacture, to the special collodion with which the finished product is finally prepared for transportation. I hope I have also convinced you that chemistry is just as essential for the successful operation of the incandescent mantle industry as it was in its inception and development.

Chemistry of Flaming Arc Carbons

Dr. **William C. Moore,** of the National Carbon Company, of Cleveland, Ohio, then presented the following paper on "Chemistry in the Development and Operation of Flaming-arc Carbons." The paper was fully illustrated by experimental demonstrations. We herewith publish it in full:

In an arc struck between two carbon electrodes, very nearly all the light comes from the incandescent electrode tips. In a direct-current arc, the positive crater is larger, and possibly at a higher temperature than the negative crater, and it is this positive crater which is the source of most of the light. Since the crater is merely an incandescent solid, it affords a continuous spectrum. Colorimetric experiments recently made by L. A. Jones and reported by him at the Cleveland meeting of the Illuminating Engineering Society, September, 1914, show that this incandescent crater has about 67 per cent of the daylight value of noonday sunlight. When volt-ampere readings are taken with such an arc it is found that if the arc is strengthened the voltage rises and the amperage falls, and eventually the arc goes out.

If we use as one of our electrodes a carbon rod which has been hollowed out into a cup, and place in the cup some potassium chloride, and again strike the arc, we find that the volt-ampere characteristics are changed and that at the same amperage a much longer arc can be drawn. Cassellmann in 1844[2] seems to have been the first to have noticed this fact. As we see, an arc fed with potassium chloride gives very little light; in fact, probably less than the pure carbon arc, as the positive crater is not so bright. This arc has a distinctive color, and, of course, would show, beside the carbon arc lines, the potassium lines in the spectroscope. Bunsen[3] in 1844 seems to have been the first to notice that different materials give different spectra in the arc.

If, instead of potassium chloride, we place a small amount of calcium fluoride in the hollow carbon cup, which, in this as in the previous case, is in the lower positive carbon, we find that the arc length for a given current and voltage is much shorter than for potassium chloride, and longer than for a pure carbon arc; moreover, the arc is intensely luminous, though rather un-

[2]Pogg. Ann. 63,576 (1844).
[3]Berzelius, Jahresbericht über die Fortschritte der Chemie und Mineral., 25, 26 (1845).

steady and liable to go out. On placing a mixture of potassium chloride and calcium fluoride in the arc, we get the combined advantages of a *long* arc, with more intense luminosity than is afforded by either the pure carbon arc or the potassium chloride arc alone. These simple facts form the starting point in the development of the modern flaming arc.

About 1899, Bremer, in Germany, brought out a flaming carbon, with calcium fluoride as the essential light-giving salt. The light afforded by such a carbon is a sensation yellow; the color is more aptly described, however, as "minus blue," as the spectrum of such an arc is very deficient in the blue.

From 1899 to the present the development of the flaming arc has been going on steadily and surely. It is interesting to note that the first record the National Carbon Company has of any work being done by them on the subject was when some ordinary cored carbons flamed and experiments were undertaken to prevent this phenomenon.

Although Bremer produced a carbon which could be burned vertically, for a number of years most of the commercial lamps were "inclined trim" lamps, taking long, cored carbons, which burned under open-arc conditions. A few years ago, however, there was developed a lamp for burning flame carbons in a vertical position, and for these lamps solid carbons have been developed. An interesting point is that the idea of solid carbons antedated the development of the lamps. These lamps generally operate in such a way that a limited supply of air reaches the arc; that is, under "enclosed-arc" conditions. These various types of lamps are doubtless familiar to the illuminating engineers present.

Modern flame carbons may be classified in several ways. From the standpoint of the mechanical structure of the finished carbon, we have cored carbons and solid carbons. From the standpoint of the color of the light emitted by the carbons, we have a major division in which are included yellow flame carbons and white flame carbons, and a minor division including red, green and blue flame carbons, red and green being but little used except for advertising purposes, and blue being used as a source of blue and ultra violet light for medicinal purposes.

In the major division, calcium fluoride is the chief constituent of yellow flamers, and rare earth compounds the chief constituents of white flamers.

A brief description of the method of manufacture of flame carbons may not be out of place. The first step, of course, is the careful weighing out of the requisite amount of the carbon base, and the proper flame materials for making a "mix." Most of these mixes are rather complex. After weighing, the ingredients are very thoroughly incorporated together and with an appropriate binder—generally tar, or pitch or a mixture of these. The "mix" is then forced by means of a hydraulic press, into long rods, which after cooling are cut into the proper lengths. These green carbons are then carefully baked in gas-fired furnaces and the temperature gradually raised according to a definite schedule, the final temperature attained being determined by a number of factors, such as the liability of some of the constituents to volatilize, or to react with each other and the carbon.

After cooling in the furnace, the carbons are unpacked, sorted, cleaned and gauged, the latter process consisting in determining the diameter, as but small variations in diameter are permissible; the carbons must also be quite straight. Some solid carbons are electroplated with copper, on the holder end to make a better contact between the lamp holder and the carbon. After plating, they are dried and made ready for shipment.

It is, of course, necessary to keep all flame carbons dry, as water may cause reactions between some of the flame materials, or may set up on a carbon-copper cell with some of the soluble or partially soluble salts as electrolytes and thereby destroy the copper coating. Water has another detrimental effect as shown by W. R. Mott[4], namely to react with the carbon at high temperatures, forming carbon monoxide and hydrogen; the latter may not only accumulate in the lamp housing and cause the lamp to explode when started again, but rapidly conducts heat away from the burning arc and lowers its efficiency.

The manufacture of cored carbons is quite similar to that of solid, except that the carbon base is different, and in forcing the die contains a pin which makes the carbons hollow. After baking, sorting and gauging this core hole is filled with a mixture of a carbon base and the flame materials with an appropriate binder, and the carbons are then dried. As cored carbons are usually very long and of small diameter, a zinc wire is inserted into a small hole parallel to the core hole. This wire increases the conductivity of the carbon. In order to make a good contact with the carbon and the holder, the carbons are "silver tipped"—that is, first copper plated, then dipped into solder, which solders the zinc protruding from the holder end, to the carbon. Such a connection is a permanent one, and is far superior to the scheme of simply bending the zinc over at the end of the carbon as the zinc becomes brittle when the core is dried and is liable to break off.

We now come to the question of desirable operating characteristics for a flame arc carbon. First of all, such a carbon should be reliable. It has been pointed out by Steinmetz[5] that after high efficiency is attained, we can afford to sacrifice some of the efficiency for reliability and other desirable factors. As will be shown below, the flame arc is already of high efficiency, hence we place reliability as our first desirable characteristic.

We may consider reliability under the four heads:

1. Constancy of distribution.
2. Constancy of light flux.
3. Constancy of color.
4. Ability to start with cold points after the carbons have been in use.

The length of the arc has a great deal to do with the amount and distribution of light. As the arc lengthens, the voltage increases; it is stated by Hechler[6] that there is a maximum definite voltage for maximum efficiency, that is, some definite arc length gives the most light.

The part that chemistry has had in increasing the reliability may be briefly indicated. It is readily seen that a flame arc which burns brightly part of the time and dimly part of the time can hardly be said to have 100 per cent. reliability if all the other factors are high. It may happen that all the flame material is evaporated from a given spot on the surface of the carbon, thereby causing a pure carbon arc for a short time. Such changes, however, are now rare, as a great deal of constructive chemical work has practically obviated this feature. As another factor affecting the reliability of operation of flame arc lamps, is the formation of slag on the points or on the lamp mechanism, it is readily seen that the proper proportion of the flame constituents and the right kind of addition agents for preventing such slags are of great importance, and here again we find that extended chemical research has resulted in the development of carbons in which this source of trouble has been largely overcome.

[4]Mott, *Electrical World*, Dec. 13, 1913, p. 1220.
[5]*Gen. Electric Review*, 17,180 (1914).
[6]Abstract in *"Electrician"* (London), 69, 658 (1912).

It has been mentioned that the flame arc is of high efficiency. The following figures are from some regular routine tests made in the laboratory.

Lamp	Current	Kind of Carbon	M.S.C.P.	Arc Watts	Watts per Candle
Excello	A.C.	Cored—yellow	1220	363	.29—
Excello	A.C.	Cored—white	843	369	.43—
Excello	D.C.	Cored—yellow	1462	445	.30—
Excello	D.C.	Cored—white	875	450	.51—
G. E. Type W.	A.C.	Solid—yellow	700	397	.56—
G. E. Type W.	A.C.	Solid—white	808	394	.49—
G. E. Lynn..	D.C.	Solid—yellow	1181	409	.35—
G. E. Lynn..	D.C.	Solid—white	939	421	.45—

The slightly lower efficiencies with the solid carbons are due to the fact that they are used in enclosed lamps, to which the air has only limited access, and so in these lamps there is less oxidation of the carbon and the flame material.

Some work by Henry P. Gage[7] at Cornell University on the efficiency of the arc stream proper may be cited here. This investigator found that, with cored yellow-flame carbons the energy radiated as light from the arc stream was 39 per cent. of the total energy radiated by it; with the arc stream from cored white flame carbons 27.5 per cent. of the energy radiated by the arc stream was light energy. The entire yellow arc showed six candles per watt radiated, while the entire white arc showed three candles per watt actually radiated.

These values are for the spectral region between 3800 and 6800 Ongström units, and for alternating current at 13.5 amperes. The following data may be presented as to the life of flame carbons:

	Life in Hours.	
	A. C.	D. C.
Cored, yellow	12.0	12.50
Cored, white	11.08	11.25
Solid, yellow	115.08	125.0
Solid, white	120.0	96.42

These figures show why the enclosed flame arc lamp is more popular than the old "inclined trim" lamp, using cored carbons.

Having indicated at a number of points the important part chemistry has played in the development of the modern flame carbon, let us now take up in greater detail some of the chemical aspects.

In the first place, the selection of the proper materials for the manufacture of flame carbons is to a very large degree dependent on the chemical properties of these materials. When we consider the carbon base, we find that the chemical behavior, as well as the physical behavior of the various so-called forms of carbon, differs with the type of carbon employed. To use an extreme case as an illustration, we know that the chemical properties of graphite differ greatly from those of lampblack. There are likewise similar differences between charcoal and lampblack; petroleum coke and retort coke. This, in part, accounts for a different carbon base being used for solid and for cored carbons.

To a greater degree than the proper selection of the right carbon base the selection of the right sort of flame material and the right sort of addition agents with this flame material has been a chemical problem. This is illustrated by the fact that to-day we know no better material than calcium fluoride for the main constituent of yellow flame carbons. I do not think I will exaggerate the matter in the least when I say that compounds of every compound-forming element have been proposed as proper substances to incorporate into flame carbons—some of them in all sorts of possible and impossible combinations.

Having selected the *right materials*, the right amount of each is our next chemical problem. That the candle power depends upon the amount of flame material is well known; more exact information on this subject,

[7]*Phys. Rev.* 33, 111 (1911).

however, may be had from the following table, which is from some work done in our research laboratory by Mr. Wm. R. Mott, using cored carbons in an Excello direct current lamp:

Parts of calcium fluoride by weight	3	2	1	0
Parts of other salt by weight	0	1	2	3
Mean spherical candle power	927	1,058	765	574

As is seen, there is a maximum per cent. of each of the constituents which will give the most light. This is true with nearly every substance which may be added to the calcium fluoride, and when we consider that flamers contain three or more substances in addition to the main constituent, it is readily seen that the nice adjustment of all these substances to each other presents some very interesting problems. It also explains why so much of our knowledge has been obtained in an empirical way. It is, of course, understood that the maxima for different addition agents do not coincide.

The chemical control of the impurities present in the raw materials is of great importance. Silica, ferric oxide and alumina, as are well known, are common impurities in calcium fluoride, and it so happens that too much of these impurities will make a poor burning carbon. Silica is especially undesirable, as calcium silicate is very non-volatile and so is a frequent cause of slag formation. The analytical difficulties in determinations of fluorine, silica and rare earths in presence of each other and of carbon are very great.

The unbaked carbon is a poor conductor of electricity. It is also rather friable. In the baking, the binder is coked and the carbon is rendered homogeneous and conducting. This coking of the binder is the chief chemical change in the manufacture of the carbon.

We now have to consider what chemical changes may occur during the burning of a flame carbon, and how these may affect the light emitted from the flaming arc. There are three possible sources of light in the flaming arc: electro-luminescence, thermo-luminescence, and chemi-luminescence. We do not know to what extent these three factors affect the light radiation in any one case. We do know, however, that in general there are two types of flaming arcs, (1) those in which the outer sheath seems to be intensely luminous, (2) those in which the core of the arc seems to be more luminous than the sheath. With very few exceptions arcs of the latter type give light of the shorter wave lengths. We have here an arc into which calcium fluoride is introduced; it is a representative of the first type; here is an arc into which chromic oxide is introduced, it is of the latter type. King has recently reported[8] that in a tube furnace almost all of the spectral lines seen in the arc spectrum of titanium appear, so that it would appear that in some cases a large proportion of the light from an arc is due to thermo-luminescence, though all possibility of chemical change was not precluded by these experiments.

Oldenberg[9] has made a spectro-heliographic study of various arcs, with some interesting results: For instance, he concludes that in the sodium arc, lines belonging to the principal series such as the "D lines" are due to chemical reactions between the vapor and the air. Band spectra seem to be of two types: those of the first type are due to collisions of atoms, in the high temperature core of the arc. The cyanogen bands always seen in a carbon arc he ascribes to collisions between carbon and nitrogen atoms. Bands of the second type are found in the sheath of the arc; they are due to undecomposed molecules; the bands of the calcium fluoride spectrum are of this type. When we consider that the

[8]*Astrophysical Journal*, 39, 139 (1914).
[9]*Zeit. f. Wiss. Photog., Photophysik und Photo. Chem.*, 43, 133 (1913).

flaming arc is a miniature electric furnace; that Fremy[19] showed years ago that oxygen converts calcium fluoride into calcium oxide; that calcium oxide and carbon react to give calcium carbide and carbon monoxide, and that the other constituents of a flame carbon may react with calcium fluoride, with the carbon, with each other and the atmospheric gases, we see that it is possible for chemical changes to play an important part in the production of the light of the calcium fluoride arc. Each of the possible substances may play its part in this light emission.

In conclusion, I think we may safely say that the past progress made in the flaming arc art has been due to the co-operation of the chemist, the physicist, and the electrical engineer; the future progress will likewise be dependent upon their combined efforts.

It might not be out of place to point out that the behavior of any one substance in the arc is determined by the conditions surrounding that substance—it behaves according to definite chemical and physical laws, and that our knowledge of these laws for high temperatures is exceedingly meager. On the other hand, once these laws are learned, it will probably be easier to build lamps to suit the carbons rather than to make a carbon to fit any and every lamp. In the extension of our knowledge of these laws, chemistry and especially physical chemistry will play an important part.

The Quartz Mercury-Vapor Lamp

Mr. **R. D. Maily,** of the Cooper-Hewitt Electric Company, presented a paper on the quartz mercury-vapor lamp. After a description of the lamp, in which special mention was made of the ground seal of invar with mercury "lock," the author emphasized that the quartz lamp is a most convenient and inexpensive form of apparatus for the production of ultraviolet rays. He then discussed at some length the effects of ultraviolet rays, especially the sterilization of water, bromination of organic compounds, photographic plate reactions, linseed oil clarification, etc., and made numerous demonstrations. The evolution of the quartz lamp has also been a development in the manufacture of clear transparent quartz apparatus.

Gaseous Electric Illumination

Mr. **D. McFarlan Moore,** of the Edison Lamp Works of the General Electric Company, Harrison, N. J., presented a paper on "Electrochemistry and the Development of Vacuum Tubes, and the Moore Light."

The author gave an interesting account of his early pioneer work begun in 1894 on "filamentless lamps." He described how in his early experiments with vacuum tubes the illumination depended on the kind of alcohol used in cleaning the tubes, how the long-tube system was worked out, how both external electrodes and internal electrodes were tried. Many experiments were made on feeding a gas to a tube or generating the gas in the tube itself. In 1896 the feed valve was perfected and experiments were made with various gases. Most interesting from a commercial standpoint was nitrogen, because it produced the most light with the least electric power consumption. Later color matching outfits were worked out, and so on.

But an immense amount of research work remains still to be done, especially along two lines. First, as to the most suitable electrodes, and second, as to the properties of the individual gases. For each individual gas there is a most suitable electrode material. Among the gases neon has become most interesting in recent times. The author concluded with a sketch of various theories on gaseous conduction and luminescent lighting.

[19] *Ann. Chim. Phys.* (3), 47, 17 (1856).

The Use of Hydrometallurgical Apparatus in Chemical Engineering*

BY JOHN V. N. DORR

This paper, although the title is somewhat general, will be devoted principally to a description of the apparatus with which my name is connected. It was prepared at the suggestion of President Whitaker who felt that it would interest chemical engineers to know of methods which have proved of definite value in metallurgical work where large quantities of material are handled with low costs.

Metallurgical engineering is really one department of chemical engineering in its broadest sense.

General Metallurgical Tendencies

Comparing metallurgical operations of to-day with the work of thirty years ago, we note that nearly everything is done on a much larger scale.

One reason for this is the general development of engineering knowledge with improved materials and the substitution of exact scientific methods for the old "rule of thumb" ways.

Another is the greatly increased demand for metallurgical products, the consumption of all the common metals having increased several times as fast as the growth of our population.

A third and perhaps most important reason is that most of the smaller rich ore deposits have been worked out so that we have been forced to attack the large low-grade deposits which twenty years ago were considered of no value.

This tendency is well shown by the treatment of the disseminated porphyry copper ores and the handling on a much larger scale of the lower-grade ores at Butte and in the Lake Superior district.

The introduction of mechanical power in place of hand labor has, of course, been as important a factor in metallurgical progress as in all other lines of endeavor.

The introduction of continuous methods in the different steps of metallurgical processes in place of intermittent methods formerly used has meant great advances.

Continuous work means invariable lower labor costs and a high load factor, thus assisting in lower power costs and interest charges. Where the change does not sacrifice control of the operation it results usually in allowing a large output of uniform nature.

As illustrations of this tendency towards continuous work in metallurgy may be noted the use of pan conveyors and rotary cylinder feeders in delivering ore to primary crushers, automatic weighing machines and belt conveyors for the transport of dry material around a mill. The belt conveyor is also in use in stacking tailings from leaching tanks and has been used to stack slime tails from an Oliver filter and dewatered sand tails from a Dorr classifier.

In smelting plants we see the use of mechanical roasters and sintering machines, such as the Dwight-Lloyd, with continuous removal of slag by granulation.

The change in cyanide practice has been quite marked. Where leaching was practiced the original means of removing slime was to collect the sand in tanks while overflowing the slime and then shovel or otherwise transfer the sand so collected to other vats for leaching.

Continuous separation, whether by cone or mechanical classifiers, has done away with this, and the sand

usually passes directly to leaching tanks without coming to rest.

In slime treatment, whether of classified slime or the whole mill feed reground, Dorr continuous thickeners have made continuous settling feasible, and continuous agitation has replaced the charge system for the dissolution of precious metals, with a very definite saving in power, attention and first cost of the installation required. The Oliver continuous filter has come into extensive use for that step in the process, and it is interesting to note that the decantation process, the first method used for the recovery of dissolved gold from slimes, which was abandoned everywhere except in South Africa on the introduction of the modern type of filter when made continuous by the use of the Dorr thickener, is coming into extensive use again and displacing in some instances an intermittent type of filter.

Zinc dust precipitation when first introduced as an intermittent process could make no headway against continuous precipitation with zinc shavings, but since being made a continuous process by Merrill has come into extensive use in modern mills.

Interchange of Apparatus in Industries

One characteristic of technological work in the last few years that was not in evidence in the centuries preceding is the exchange of information among workers in different fields.

Although the total knowledge in the world has increased so enormously, and this has been called very properly an age of specialization, the specialist is expected to have a general knowledge of progress outside his own field to such an extent that he can profit by it in advancing his own work.

This has been made easier in metallurgy more than in chemical engineering, I should say, by the greater freedom among metallurgists in the exchange of data. A valid reason for this is that the metallurgist competes in a much greater degree with natural conditions than with other producers of the same product.

The price of gold is essentially constant whether more or fewer mines are operating and, while the prices of silver and the base metals vary with the supply and demand, the profits made depend so greatly on other factors, such as richness of the ore and costs of mining and milling, that I doubt if any producer would hope to get an advantage over the others by secrecy. In fact, there is a general understanding among the larger copper companies to-day for an exchange of information which gives them all an advantage in the combat with Dame Nature.

In manufacturing, on the other hand, there is theoretically competition for the purchase of the raw material and the sale of the finished product so that manufacturing costs and profits must come between the two, and any advance that can be made in reducing the former unless kept from competitors seems of no real benefit.

The cyanide process has been benefited by the adoption of methods and machinery from other industries and has made its own contributions in return for benefits received. Fine grinding has been aided materially by the adoption of the tube mill from cement grinding, and when dry crushing and chlorination on Cripple Creek ores was in vogue the inclined traveling screens used in clay working were of great assistance as were the dust collectors taken from Minneapolis flour mills.

Our early paddle arm agitators came from chemical works and the air-lift agitator, or "Pachuca" tank which succeeded them, was first used, I am told, in a powder plant in California.

The Dehne filter press, so extensively used in Australia, was another adoption from chemical industries, and the rotary drum filter was used in Syracuse as a dewaterer of chemical precipitates before the cyanide process was known.

As developed by Oliver, with means for washing and blowing off the cake formed, it has been returned by the cyanide operator to several industrial uses.

Various forms of vacuum and pressure "cake" filters, such as the Moore, Butters, Kelly and Sweetland, might be said to have their prototype in the potter's method of making pitchers. This is done by pouring "slip" into a plaster of Paris mould and when a solid deposit has been formed by the absorption of moisture pouring out the remainder of the liquid "slip" and drying the vessel thus formed in the mould. From cyaniding they have found their way extensively into sugar refining, alkali work and many other lines. The Merrill sluicing press is being installed in a large aluminium plant in the South.

In closing this general discussion I will say that, while the basic principles for the mechanical treatment of analogous materials are the same, great caution should be used in proposing the substitution of any method or apparatus successful in some other field for that now used. It is safe to assume that the latter is in use as a result of much study and gradual development, and its replacement should be preceded by a most careful detailed study of all the conditions of operation and purposes to be accomplished.

Suggestions as to such substitutions may be advanced tentatively, but an actual demonstration is worth a lot of theorizing. In introducing new methods we usually find troubles come where not expected, and apparent difficulties do not prove real.

The Dorr Apparatus—General

The apparatus which I wish to call to your attention was developed by me in the last ten years in the course of operating cyanide mills in the West. Each machine performs a certain useful function satisfactorily and economically, and I feel that you will agree with me that where similar work is to be done they are worthy of consideration. I do not mean, of course, that a machine adapted for handling a sandy pulp is necessarily the best type to handle an extremely light chemical precipitate, but I feel that where the operations of washing, settling or agitation are required they may be of service.

As a generalization, I believe I am safe in saying that machinery successful in operations where costs per *ton* are studied to a fraction of a cent, have possibilities where materials are handled on which costs per *pound* are watched. It is true, on the other hand, that the economies of continuous work decrease with a reduction in tonnage, so that each case has to be studied by itself. In discussing the apparatus I have of necessity quoted freely from my paper on the same read at the Salt Lake meeting of American Institute of Mining Engineers in August, 1914.

The Dorr Classifier

This machine was devised by me in 1904 to replace hydraulic cones for the purpose of making a separation of sand and slime at the mill of Lundberg, Dorr & Wilson at Terry, South Dakota. The method of cyaniding the gold ore in use at that mill was crushing to pass a 20-mesh screen, separating the sand from the slime, leaching the sand in vats by percolation and treating the slime after agitation and thickening by the Moore filter process. The machine proved such an improvement over the cones in use at our plant and elsewhere that it was rapidly adopted and has come into wide use. It has been improved from time to time to meet new

conditions and as now manufactured is shown in Fig. 1, which illustrates the standard duplex machine.

The Dorr classifier consists of a settling box in the form of an inclined trough with the upper end open, in which are placed mechanically operated rakes or scrapers for the purpose of removing the quick-settling material from the open end, the liquid and slime overflowing at the closed end. Each rake is carried by two hangers, one at the sand-discharge end suspended from
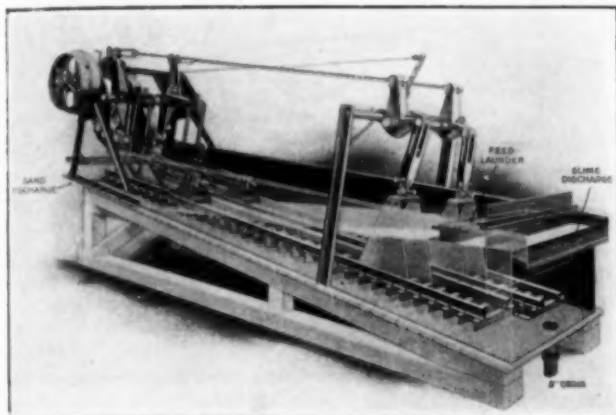

FIG. 1—THE DORR CLASSIFIER

an arm attachment to a rocker arm or lever which terminates in a roller. The other suspends from a bell crank connected by a rod to the same rocker. The roller is kept pressed against a cam on the crankshaft by the weight of the rakes.

The rakes are lifted and lowered at opposite ends of

REGULATION OF PRODUCTS

The machine is intended, of course, to make only two products, and the point of separation can be varied by the following means:

1. The use of the baffle shown, which allows a reduction of the cross-section of flow so as to overflow more fine sand.

2. Raising the rakes and thus obtaining the effect of operating them in a shallower tank.

3. Increasing the speed of the rakes until the agitation keeps fine sand in suspension.

4. The attachment of perforated spray pipes to the rakes at a point where they remove the sand from the liquid, allowing a rewashing of the sand and removal of any slime that may be carried down with it.

This latter feature will probably be of more interest from the chemical engineer's standpoint as enabling him to discharge finely divided sandy material and give it a complete wash to free it from any dissolved material which adheres to it.

CAPACITY

The capacity of the Dorr classifier depends upon the dilution of the feed and the point of separation which it is desired to make. The rakes of the Simplex machine, operating at normal speed, are able to discharge at least 150 tons of solids in 24 hours.

Table I, showing results at different plants, will give the best idea of what may be expected.

COST OF OPERATION

Experience has shown that repair costs on these machines are extremely small. I know of one classifier which operated nearly four years with repair costs of

TABLE I—OPERATING DATA ON DORR CLASSIFIERS

Mill	Tons per 24 Hr.	Dilution	Feed +100	Feed +200	Feed —200	Sand +100	Sand +200	Sand —200	Slime +100	Slime +200	Slime —200
Portland, Colorado	145[a]	5 to 1	38.3	13.4	47.1	75.3	16.2	7.4	0.9	5.8	94.7
Golden Cycle, Colorado	151[a]	3.5 to 1	45.0	19.0	36.0	68.0	23.0	9.0	...	11.0	89.0
Cia Benef. de Pachuca, Mexico	144[b]	4 to 1	42.7	25.1	32.5	43.6	40.1	16.8	0.1	3.8	96.8
Tonopah Extension, Nevada	73[c]	6 to 1	65.0	11.1	23.9	70.0	18.3	11.7	0.6	8.5	90.9
Amparo Mining Co., Mexico	125[c]	7.5 to 1	52.4	18.5	29.1	71.4	27.4	1.2	...	6.5	93.5
Tonopah-Liberty, Nevada	85[c]	7 to 1	30.5	41.9	26.3	75.7	24.0	0.1	2.5	14.3	81.4
Goldfield Consolidated, Nevada	264[d][b]	3 to 1	40.0	12.0	48.0	74.0	19.0	7.0	2.6	19.5	79.1
Tonopah-Belmont, Nevada	70[c]	.....	65.6	2.7	28.9	....	....	....	0.4	6.6	93.0
Alaska-Treadwell, Alaska[e]	89[c]	.....	48.7	41.5	9.8	48.7	41.5	9.8	...	2.0[c]	98.0
Nipissing, Canada	...	.....	78.7	3.6	16.8	85.8	7.2	6.9	...	0.5	99.5[f]

[a] New ore.
[b] Includes tube-mill return. Under normal conditions, with a tube mill in closed circuit with a Dorr classifier, 35 to 50 per cent. of original feed returned.
[c] New ore; tube-mill product returned, but amount not stated.
[d] 168 tons come from the stamps, the rest being returned from the tube mill.
[e] Classifiers used in connection with the regrinding of concentrator; rakes operated 24 strokes per minute; 100 per cent. of concentrates pass 200 mesh; the 2 per cent. is silica from tube-mill pebbles.
[f] Of this 200 mesh product 15 to 20 per cent. is sand; crushing is done in two sets of tube mills; the sand from the first classifiers being reground in closed circuit with the tube mills and other classifiers, the combined slime overflows giving the screen test shown.

the stroke by the action of the cams transmitted through the rocker arms and bell cranks, and the horizontal motion is obtained directly from the crank.

The bell cranks at the slime end are carried by a second larger bell crank held in position by a chain attached to a spool on a worm gear at the head end of the classifier. By this means the rakes can be raised 10 in. at the lower end and operated in that position or any intermediate one. This allows the classifier to be started readily when nearly filled with sand after an unexpected shutdown, and the regulation of the depth of the settling box when in operation to vary the products being made.

The pulp is fed across the settling box as shown and a uniform flow to the lip at the end is maintained, while the sand settles to the bottom and is advanced by the rakes until it emerges from the liquid and is discharged with from 20 to 30 per cent moisture.

The agitation near the bottom of the tank caused by the reciprocating motion of the rakes assist in keeping the slime in suspension, but is not normally sufficient to cause fine sand to overflow.

less than $5, and a half a mill per ton seems a safe figure. While the power taken will vary of course with the load, it appears that $\frac{1}{4}$ horsepower is ample in most cases. With normal feed the attendance required is practically nothing, being limited only to an occasional oiling. All parts in reciprocal motion are removed from contact with the liquid, so that there is no opportunity for wear starting at any point.

USES

Besides being used to separate a leachable sand product from slime, Dorr classifiers are in general use to-day in connection with fine grinding.

Fig. 2 shows the arrangement of Dorr classifiers and tube mills operating in closed circuit in the Tonopah-Belmont mill. It is considered much more economical in power and equipment when a product 150 mesh or finer is desired, to pass a large tonnage continually through a tube mill, return the discharge to a Dorr classifier and overflow the part which is ground fine enough, returning the balance to the same machines for further grinding, together with the sand coming

from the new feed. This is considered much more efficient than to attempt to reduce the product to the size required in one passage through the tube mill. It

through Nos. 5 and 4 to No. 3, thus effecting a counter-current washing. The overflows from Nos. 1, 2 and 3 after clarifying were sent to electrolytic precipitation.
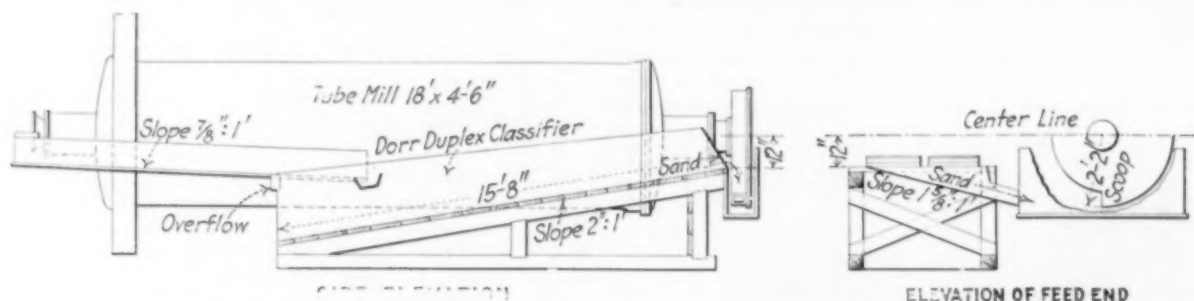

FIG. 2—ARRANGEMENT OF DORR CLASSIFIERS AND TUBE MILLS OPERATING IN CLOSED CIRCUIT IN THE TONOPAH-BELMONT MILL

seems more than probable that it will prove equally advantageous in connection with industrial pulverization of quartz, cement material and other mineral products that require fine grinding. Some work has already been done on thes lines, especially in connection with pigment grinding, but I have no data that are at present available.

Dorr classifiers are now in successful use as dewaterers of concentrates, both magnetic iron concentrates and sulphides, and are discharging the former at one plant with only 12 per cent. moisture.

LEACHING

The use of a series of Dorr classifiers for the purpose of leaching and washing was first suggested by Mr. Utley Wedge, and some experiments were made along that line several years ago but not carried to a conclusion. Last year Captain Wolvin of the Butte-Duluth Company at Butte, who was leaching oxidized copper ores in vats there, brought up the same idea and we furnished him with five classifiers for trial, with all parts, subject to contact with the acid, made of hard wood. These machines proved very successful, increasing the extraction over the former leaching in vats at least 20 per cent. and we have since then furnished them with more machines for the same purpose. Fig. 3 shows the discharge of tailing from the last machine of a series.

I have been unable to get reliable detailed results of these operations, as they have been changing details from time to time, but the following data obtained last summer from the Butte-Duluth Company, when the first installation, consisting of six small classifiers, was in use, will give an idea of the operations at that time.

6 Classifiers in series, 5-15' x 4½', 1-30' x 4½'.
Ore crushed through .12" opening in inclined impact screens, giving a product of about —10 mesh.
Value of heads..................................2.14% Cu.
Average strength, H_2O_4 acid used.......................7.33%
Ratio of solution to ore............................2.25 to 1
Moisture in discharged tails...........................20%
Extraction 89.9%
Value of solution going to cells.....................1.8% Cu.
Value of solution from cells...........................9% Cu.
Speed of Classifier rakes, strokes per min..................6
H.P. (motor 86% efficient)..............................4.6

The average daily capacity for the month in which the above figures were obtained was about 150 tons. The limit to the capacity was the lack of electrolytic cell room.

Spent electrolyte after strengthening was added to the first two classifiers and water into No. 6. Most of the overflow from the latter went to scrap iron precipitation and an amount equal to the acid liquor brought out from No. 5 with the ore was carried

The ore received about 40 minutes' contact while passing through the whole series.

TRIPLE-WASHING CLASSIFIER

Fig. 4 shows a machine which we have designed to wash a sandy material absolutely free from any trace of slime or to wash the same kind of material entirely free from any liquid in which it may be suspended. It

FIG. 3—TAILING DISCHARGE BUTTE-DULUTH COPPER LEACHING PLANT

will be noted that there are a number of opportunities to get rid of the liquid or slime mentioned.

First, as the sand is raked up above the water level in each box it is sprayed with any solution or water. Second, as it is washed into the following box it is diluted with the same liquid, so that in all it gets a very thorough treatment.

POSSIBLE USES OF THE CLASSIFIER

Several Dorr classifiers are now in operation at one of the mid-Western chemical works, used, I believe, for draining a granular chemical precipitate and washing
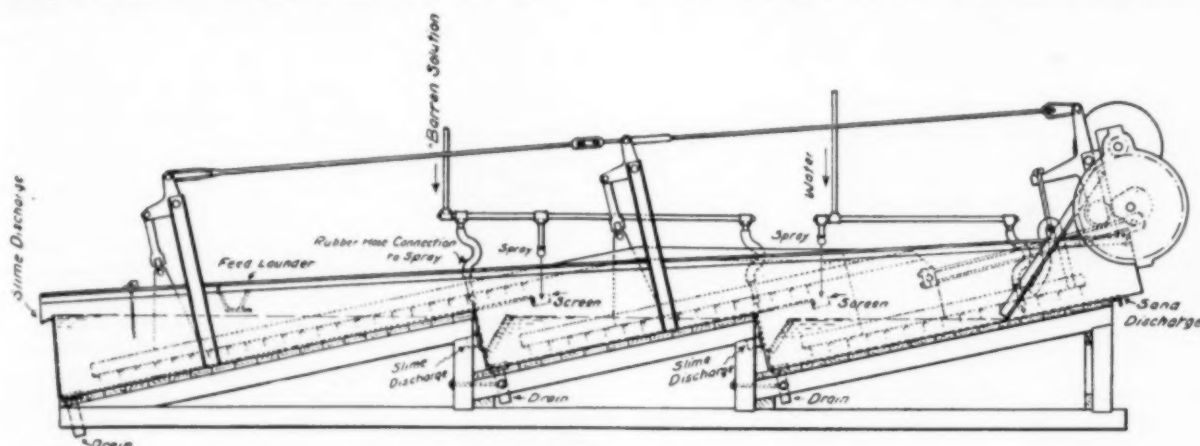

FIG. 4—THE TRIPLE-WASHING DORR CLASSIFIER

same. Its use in connection with clay-washing in the preparation of a high-grade kaolin, in place of the settling boxes which now require a great deal of labor for removing the sand from them, is now being considered and its use for dewatering or removing granular material from any liquid will be apparent.

(To be concluded in the February issue.)

The Chemical Trade Situation in Germany and Great Britain

(From the London *Engineering*, December 4, 1914.)

The much-discussed subject of the control by Germany of a large portion of the chemical industries came before the Society of Arts [in London] on the two last Wednesdays in connection with two papers read respectively by Sir William Tilden and by Mr. W. R. Ormandy, D.Sc. Neither speaker took what we may briefly designate as the commercial point of view, nor did either enter into details of technical problems; Sir William Tilden gave a few statistics, Dr. Ormandy none at all. Both accentuated the general development of industry on methodical scientific lines, and as Dr. Ormandy adopted the more general and broader standpoint, we will begin with his lecture of last Wednesday.

Lord Moulton, the chairman, opened the proceedings by a few words, which made a deep impression. Speaking under visible emotion, and in terms which would have commanded the respectful assent of men of any nationality, he said that he had had to investigate the question of the supply of certain chemicals formerly obtained from Germany, and the facts were a cause for sadness and national humiliation. The chemical industry, except those branches which required least knowledge, thought, and least study, had, for reasons, perhaps, of our manufacturers being too well off, or of sluggish intellect, been allowed to fall into other hands. It was not that England was incapable or unfitted for the industry. They had to look for some fault in their national character or in their national behavoir, and they had to learn from the enemy. The most glorious moment in Prussia's history had not been their military success, but the period of deepest distress following 1806, when men like Fichte had not spared them, but had told them that only self-discipline and recognition of their national faults could help them to regain their self-consciousness and honorable position. Our position was not that of Prussia after Jena, but it was grave enough. Something more than contemplation of immediate profit was required; we had to rouse ourselves to save ourselves from German industrial domination, as well as from her military domination.

In commencing his remarks, Dr. Ormandy pointed out that when the introduction of the steam engine as a means of power and transport had rendered industrial development on a large scale possible, Europe outside the United Kingdom was in an unsettled condition, and this country could thus become the workshop of the world. British manufacturers paid low wages for long hours, and made enormous profits. Orders for steel and tools were given without much inquiry about prices, provided quick delivery could be guaranteed. The subsequent rapid development of foreign countries demanded capital for railways, shipping, mining, etc., and the best returns could be obtained from such ventures. English spinners and weavers were supplying the world with their products, while loom and mule machinery makers worked night and day to supply the infant foreign industries with the machinery necessary to compete with England in markets in which this country had held a monopoly.

The commercial life of Germany might be said to have commenced little more than a generation ago. An inland country, with little seaboard, few raw materials, no iron ores comparable to Cumberland hematites, and rather poor coal in distorted seams, Germany had seemed at a huge disadvantage. It was early recognized, however, that progress could not be left to individualistic effort. Too much credit could not be given to the far-sighted way in which problems of agriculture and industry were in Germany regarded from a national standpoint, while in this country [Great Britain] individualism was running rampant. The very people whose fathers had sold land to the railway companies at absurdly inflated prices now complained that, owing to the high freights, they could not make adequate profits from the investment of the money obtained from the same railway companies by an earlier extortion. In Germany afforestation was compulsory; enormous areas, fit for little more than potato cultivation, enabled Germany to produce glucose, starch and alcohol for all Europe. The iron exports, twenty years ago also insignificant, now exceeded the British exports by nearly 100 per cent. Realizing that all industrial progress was becoming more and more scientific, and that the adequate utilization of the by-products might settle the survival of the industry itself, by-product recovery coke-ovens, which also supplied the raw material for dyes previously obtained from England, were installed in the imme-

diate neighborhood of the blast-furnaces, and the surplus gas from both was utilized for power generation. Favored by Nature to an extraordinary degree as to pottery, English workmen had acquired a wonderful skill for the production of objects of art; but when the demand arose for complex porcelain castings of high-insulating capacity, Germany was able to secure that market.

The lecturer then passed to other features. Some one said that a nation got the newspapers it deserved. Judging by what had recently appeared in some portion of the [British] daily press upon German trade, it was devoutly to be hoped that the common-sense of the British nation would not be judged thereby. During the past ten years more than sixty millions of Germans had been fully occupied in industrial operations; our own [Great Britain's] population had equally fully been occupied, and yet people wrote as though there were a possibility that a large proportion of the activities of the larger nations could profitably be undertaken in a smaller country whose own workpeople had for the most part been quite busy.

Passing to the German willingness and ability to work in co-operation and to the great help afforded by banks to industry, Dr. Ormandy said that the heads of German banks were men of high technical knowledge, and not stockbrokers or retired colonels. These men were accessible to the inventor and ready to avail themselves of technical experts of the highest class to investigate new processes.

The other lecture upon "The Supply of Chemicals to Britain and Her Dependencies," which Sir William Tilden, D.Sc., F.R.S., delivered at the Society of Arts on Wednesday, the 25th ult., was more a plea for scientific research than a commercial review or a statistical compilation. "There is only one road to permanent industrial success, and that is the way pointed by science," was Sir William's advice to the chemical manufacturer. It was the old story in a new garb: chemical industry—some branches of it, at least—had migrated from this country [Great Britain], its original home, to Germany, and the country was now, the speaker said, in want of products which it ought to produce itself.

In his introduction, Sir William Tilden pointed out that Germany had contributed little to laying the foundations of theoretical chemistry a century ago. There had been no German chemist of the first rank, and only one fundamental German discovery, the discovery of isomorphism by Mitscherlich in 1819. Liebig, born in 1803, was the first of the great German chemists. If Professor Tilden had gone three years further back, to the beginning of the century in 1800, he would not have overlooked the birth of Friedrich Wöhler, a man whom chemists are justified in revering as one of the first men of his century and as the father of synthetic organic chemistry, in which, Sir William afterward remarked, "the most remarkable successes have been won, though not wholly, as sometimes represented, by the German chemist."

Turning to the position of industrial chemistry, Professor Tilden quoted the report on chemical processes and pharmaceutical products and processes at the second International Exhibition of 1862, by August Wilhelm Hofmann, then Professor of Chemistry at the Royal College of Chemistry and Mines: "The contributions of the United Kingdom have not only maintained their preeminence, but outdone their own admitted superiority on the corresponding occasion of 1851." Of 762 exhibitors in the class, 200 belonged to the United Kingdom, 136 to the Zollverein and 115 to France. The statistics of Allhusen and of Gossage showed that the production of heavy chemicals (alkalis, acids, manures,

etc.) had nearly doubled between 1852 and 1862. Recent Board of Trade statistics proved that in these respects British manufacturers had no need to fear German competition in the home market.

But it was different in coal-tar dyes, drugs, antiseptics, essential oils, aromatic substances, materials for photography, pure chemical reagents, and the many other indispensable products of modern chemistry. The sources of supply of all these materials in the United Kingdom was seriously inadequate. In alizarin, anthracene, aniline, etc., dyes this country imported from Germany, in 1913, goods totaling £1,653,600 in value, and, further, £76,681 worth of synthetic indigo. Drugs, including medicinal preparations, were imported in the same year to the amount of £1,302,860, and more than one-fourth of these came from Germany, to which only £24,690 worth of coal-tar products were exported. No figures were available as to fine chemicals for analysis, but he might safely say that there was no appreciable production of these things in Great Britain. If that statement were to be met by protests from manufacturers, it was only necessary to refer to the experience of analysts and directors of research laboratories, who had habitually to resort to German makers for their supply of trustworthy reagents.

A chemical manufacturer, discussing the neglect of fine chemicals in this country, had recently remarked, "What does it matter if we are making money?" "I venture to say that that view expresses neither patriotism nor common sense," was Sir William's comment. German chemists were, indeed, attacking the market for heavy chemicals already. They, Sir William continued, exported three times as much sulphuric acid in 1912 as the United Kingdom did in 1913, and they arrogated the whole field of scientific and industrial chemistry to themselves.

In support of this statement, Sir William mentioned that Emil Fischer, in delivering the inauguration address of the Kaiser Wilhelm Gesellschaft zur Förderung der Wissenschaften, had suppressed every foreign name except that of Perkin. That is not quite correct; Sir William was rather severe, and he might, we venture to suggest, have clothed his allusion to that institution in such words as to further his own object—the promotion of scientific research. The facts are that large sums of money had been collected for the advancement of science; German chemical industry, though prosperous, wanted her institution for chemical investigation; the scheme became more and more ambitious, as money poured in, and to make further propaganda Emil Fischer traced in his address the relationship between science and chemical industry in Germany. It was a *pro domo* speech, not rich in names; there was no particular reason for introducing foreign names; yet, we grant, Fischer should not have confined himself to Kelvin, Perkin, Dewar, Berthelot and Baekeland.

In recalling the circumstances which had led to the gradual transference of the color industry from England to Germany, and to the failure to establish here any appreciable production of synthetic drugs and chemicals, Sir William Tilden regretted that A. W. Hofmann was allowed to return to Germany, where a Chemical Society was only founded in 1867, while the Chemical Society of London dates from 1841, and he blamed the antiscientific spirit and the neglect (up to 1885, at any rate, when Sir William Perkin commented upon it) of research by the old universities of this country [England].

That had quite been altered since then; yet it was necessary to insist that no man should be appointed a professor of natural science who had not shown his ability by original research, and the professor should have a sufficient staff of properly-trained assistants to

enable him to pursue a promising line of investigation. Forty years ago British chemical works had no qualified scientific chemists; in the palmy days of color-making hardly any British manufacturers probably had ever heard of Kekulé's benzine-ring theory, to which German chemists primarily ascribed their prosperity. German indigo had almost driven the Indian planter from the field; the value of natural indigo from India imported into this country [Great Britain] had fallen from £124,112 in 1909 to £48,208 in 1913, while £76,861 worth of synthetic indigo had been imported from Germany in 1913, as mentioned above. "The strength of our competitors is in their laboratories, and not, as here, on the Exchanges," Professor Meldola had said. The maxim which we quoted in our first lines was indirectly suggested to Sir William by a lecture, delivered by H. Brunck, on "The History of the Development of Indigo," at the Hofmann House in Berlin in 1900, which lecture, Sir William said, "might be regarded as a sermon preached to British manufacturers."

In order to render the Empire independent of supplies from foreign sources, Sir William stated the industry wanted many first-rate chemists, a few engineers, plenty of capital, and some good men of business. It was right to learn from the enemy. British universities could supply the chemists if manufacturers would treat them more reasonably and liberally. The German large works took young university men on the recommendtion of the professors, placed them under the chief chemist of the department in the research laboratory, and paid them a salary sufficient to live modestly; their future depended upon their ability. The engineer was, of course, indispensable. As regards buildings, structures, supplies of water, fuel, power, and electricity, the engineer had the field to himself; but the chemist ought to be supreme as to chemical operations, and in the dye manufacture, e.g., the chemist at present required little assistance from the engineer. We should submit, however, that in the practical adaptation of a process success will much depend upon the engineer. It has been acknowledged that Knietsch finally was able to make the contact sulphuric acid process a success because he was a first-class engineer as well as a chemist.

Sir William, in concluding, said that the establishment of what would practically be a new industry (after the war) would require State aid, and that aid had been promised to the dye industry; it would have to be extended to those chemical products on which the dye manufacturer depended.

In inviting discussion of the paper, Sir William Ramsay, the Chairman, in strange contrast to Lord Moulton, said that the Germans organized a chemical trade campaign as they organized a war. Expert committees looked out for new markets and raw materials, created a demand for them, had agencies all over the world, advised as to loop-holes in patents, and framed the patent laws so as to exclude the foreigner, all this with State aid bounties, export duties, &c. Some British works were, of course, quite as splendidly equipped as German works; but the small manufacturers had to be protected by organization, lest they cut one another's throats.

Professor James J. Dobbie, of the Government Laboratory, agreed with the lecturer, and referred to one point, the unreadiness of the British chemical manufacturer.

Professor A. G. Green, of Leeds, said that the question was simply one of knowledge; the Germans considered it worth while to pay for it, over here we did not. He would give a characteristic case. A firm wishing to take up a new explosive advertised, not for a chemist, but for a workman acquainted with the process; they got one formerly with a rival firm; he wanted fuming sulphuric acid, and the firm again advertised for a workman.

Dr. Chapman pointed out that in the science of brewing England was certainly in the forefront, to which the lecturer readily assented; he had deliberately omitted reference to brewing.

Mr. Walter Reid complained that the British inventor had to go abroad to get his invention worked. He had made the first smokeless powder, and offered it to the government, but his offer had been declined because they would have had to change their rifles. The British manufacturers were an untrained mob against an organized army. He had his doubt about government factories; the Board of Trade should really do something for trade, and be an advisory body; success of the National Physical Laboratory was largely due to the guidance it received from the general board, on which practical men had seats.

Mr. C. E. Cassal, of London, stated that if chemists were advertised for at £65 [or $325] annually, and Honors men were offered a final maximum of £150 or £200 [or $750 to $1000] as chief chemists, nobody could expect able men to select the chemical profession.

Sir William Tilden, in his final brief reply, repeated that the German works did not offer their staff more. Those men came direct from the universities, and had to learn their business first; no college could teach industrial chemistry.

Synopsis of Recent Chemical and Metallurgical Literature.

Gold and Silver

Precipitation of Gold from Solution—A method for the exact precipitation of gold from a solution, for example, after it has been separated from silver and platinum group metals, is given in the September, 1914, *Journal* of the Chem., Met. & Min. Soc. of S. Africa, by Mr. H. R. JOLLY. The solution of gold in aqua regia is "neutralized with a 20 per cent caustic soda solution. The beaker is then put on a hot plate, the contents warmed gently, and about 5 to 8 cc of a warm 10 per cent solution of potassium cyanide added, and the solution allowed to stand for about ten minutes. Thirty cc sodium sulphite 20 per cent solution are then added, and the beaker allowed to stand for about ten to fifteen minutes longer on the hot plate, after which it is removed and the contents diluted to about 300 cc. The process to follow is the same as the precipitation of a cyanide solution by Mr. Whitby's method. The reagents are added to the solution in the following order and quantity: 8 to 10 drops of 10 per cent potassium ferrocyanide, 30 cc of 20 per cent copper sulphate, 30 cc 20 per cent sulphuric acid, and 10 cc sodium sulphite. It is absolutely necessary to stir the solution after the addition of each reagent. The precipitate is allowed to settle and collected on a filter paper; after draining, the filter paper and its contents are put into a No. 1 assay pot, fluxed and fused in the ordinary manner. The lead button obtained is cupelled, the bullion bead parted and the gold weighed.

"Check gold was dissolved up in dilute aqua regia and treated as above. The following table shows the results:

Original Weight.	Weight after Treatment.	Loss	Percentage Extraction.
½ mgm.	½ mgm.	½ mgm.	
24.54	24.50	0.04	99.83
34.74	34.73	0.01	99.97
30.44	30.44	. . .	100.00
10.22	10.20	0.02	99.80
26.45	26.40	0.05	99.81

"According to Watts' *Dictionary of Chemistry*, potassium auricyanide is formed by adding neutral gold chloride solution to a hot concentrated solution of potas-

sium cyanide, and it is on this reaction that the forego-
ing method is based. It is, however, necessary to re-
duce the gold to the aurous state in order to get com-
plete precipitation, and this is accomplished by adding
sodium sulphite."

Chemical Engineering

Removal of Sulphurous Acid from Fumes.—In an
editorial on progress in fume recovery in our November
issue (page 670) reference was made to a German in-
vention for the elimination of sulphur dioxide from fur-
nace gases by means of dicalcium phosphate. As sev-
eral inquiries have been made concerning this process,
we give here some details from the patent specification,
although the patent is not of recent date (German pat-
ent 160940, class 12*i*, granted on May 26, 1905). The
inventors are Eugen Bergmann and Theodor Berliner.
If dicalcium phosphate is used as absorbent in presence
of water, the sulphur dioxide decomposes the dicalcium
phosphate according to the equation

$$2 \ Ca \ H \ PO_4 + 2 \ SO_2 + 2 \ H_2O = Ca \ H_4 \ (PO_4)_2 + \\ Ca \ (HSO_3)_2.$$
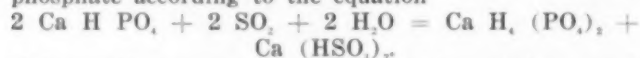
This reaction occurs at ordinary low temperatures, and
by this reaction it is possible to absorb the sulphur
dioxide even from fumes in which it exists in great dilu-
tion. By a simple moderate elevation of the tempera-
ture to not more than 100 deg. C. it is then later possi-
ble to regenerate the dicalcium phosphate and recover
the sulphur dioxide, since at the higher temperature the
above reaction proceeds in the opposite direction (from
the right to the left of the equation). The process is,
therefore, cyclic with respect to dicalcium phosphate
which alternately absorbs and gives off sulphur dioxide.

Lead Acetate Test for Hydrogen Sulphide in Gas.—
The effect of the following factors upon results obtained
in tests for the detection of hydrogen sulphide in gas
by the lead acetate test has been investigated by the
Bureau of Standards, Department of Commerce, and
will be published in the forthcoming Technologic Paper
No. 41 of that bureau: (1) The paper, kind, method
of preparation, including the strength of lead acetate
solution used, and the moisture content when used.
(2) The gas, its humidity, and the period and rate of
flow. (3) The apparatus, its form and size, as de-
termining the circulation of gas with respect to the
paper. With gas mixtures containing various known
amounts of hydrogen sulphide these several factors
were studied one at a time and the following conclusions
reached: (1) An operator, by giving consideration to
the desirable qualities which are pointed out, can easily
select the most suitable and convenient kind of paper
after a trial of a number of samples; the convenience,
but generally not the accuracy, of the test is affected
by the choice. There is little or no difference in the sen-
sitiveness of the paper prepared with lead acetate solu-
tion from 2 to 12 per cent in strength; a 5 per cent
solution is recommended. Treatment of the papers
with ammonia or carbon dioxide does not materially
change their sensitiveness. It is recommended that the
test paper be dipped in lead acetate solution, blotted,
and used moist, since such paper gives the most relia-
ble results. (2) The large effect of the humidity of the
gas upon the test results is shown; but it is also noted
that the use of moist paper with short test periods (not
over three minlutes) gives results practically inde-
pendent of the humidity of the gas. It is impracticable
either to dry or to saturate the gas to a constant con-
dition as to humidity, because of the probability of
simultaneous change in the hydrogen sulphide content.
(3) The rate of gas flow has some effect, but increases
in rate produce less effect than proportional increases
in the time of test. The general practice of making
tests at 5 cu. ft. per hour is satisfactory; maintenance
of the rate within the limits 4.5 and 5.5 cu. ft. per hour

is sufficient. The time of test is an important factor in
determining its sensitivity; the proper basis for selec-
tion of the length of test is treated in connection with
the discussion of the quantitative and engineering
significance of the tests.

The different forms of testing apparatus used may be
classified into three groups, circulating, impinging, and
penetration, these being distinguished by the manner in
which the gas is brought into contact with the paper.
The five forms of circulating apparatus tested were:
The simple hydrogen sulphide tester, chosen for this
work and designated in this paper as standard appara-
tus;; the Referees apparatus; the Young's sulphur and
ammonia test apparatus; the small drying-tower form,
and a large Woulff bottle. Only one very simple form
of the impinging type was tested; and a single penetra-
tion apparatus, devised in the bureau, was used. The
variation in the tests with different forms of apparatus
is largely due to the variation in intensity of the gas
currents and their direction in relation to the paper.
In the small drying tower the test paper was suspended
close to the rubber stopper bearing the burner and a
much larger proportion of the gas came in contact with
the paper than in the other forms of apparatus. Al-
though the Woulff bottle had a larger capacity than the
Referees apparatus it consistently gave a stronger test
than the latter, showing that size alone is not a de-
termining factor; the shape of the apparatus and the
location of the paper relative to the inlet and outlet have
an important influence. It has been generally recognized
that a test in which the gas impinges on the paper is
more sensitive than one in which the gas does not im-
pinge; this is due to the better opportunity for contact
of the gas with the reagent on the paper and to the
small area within which the lead sulphide is concen-
trated. And a similar increase in sensitiveness is ac-
complished by causing the gas to be tested to pass
through the paper, as is done in the penetration appa-
ratus described. This increase in sensitiveness due to
impingement of gas on paper seems to have been over-
estimated by some, however.

The important influence of the shape and size of the
apparatus upon the result of tests made with it, makes
clear the necessity of an exact specification of the form
and size of the tester. It is therefore recommended that
the specifications given for the apparatus which is used
as standard in this work, be followed exactly in making
the tests. When the test is made under definite condi-
tions, the coloration produced is of quantitative sig-
nificance as indicating the amount of hydrogen sulphide
present in the gas. The results which are obtained by
the procedure recommended as standard are shown to
have the following significance. The test, if of one
minute duration, will detect about 0.3 to 0.4 grain
hydrogen sulphide per 100 cu. ft. of gas. But if the
test is of 0.5 minute duration, about 0.45 grain of
hydrogen sulphide is required to give a test; if extended
to three minutes a gas of about 0.2 grain will give posi-
tive results. The Young's apparatus is slightly more
sensitive than the standard form, but the Referees ap-
paratus is less sensitive for it will scarcely detect 0.5
grain of hydrogen sulphide per 100 cu. ft. of gas when
used with moist paper for three minutes at a rate of 5
cu. ft. of gas per hour.

The penetration apparatus is somewhat more sensi-
tive than any of the forms of circulating apparatus.
The sensitivity of the apparatus of the impinging type
is variable, depending upon the rate of gas flow, dis-
tances of jet from paper, etc.; but under the most
favorable conditions apparatus of this type is the most
sensitive of all. No direct comparison can be made
with the work of some of the previous observers, but it
is certain that too great a sensitivity has been ascribed

to the procedures used by these experimenters. The commercial significance of the testing procedure recommended is pointed out. It is stated that many tests of similar severity and some a great deal more severe have been met regularly in the past, showing that the proposal is certainly not unreasonable. The method recommended for use is quick and convenient and gives reproducible results; and a simple and inexpensive form of apparatus is described which can easily be constructed by inexperienced persons without any sacrifice of the advantages due to exactness of specifications. The importance of conforming to the specifications, both as to the apparatus and the procedure in testing, is pointed out.

Recent Chemical and Metallurgical Patents
Copper, Lead and Zinc

Flotation of Carbonates by Previous Conversion Into Sulphides.—Since oils manifest a greater affinity for sulphides than for carbonates or oxides, Mr. JOSEPH T. TERRY, JR., of San Francisco, Cal., proposes by a patented process to convert such oxides or carbonates into sulphides and then recover the same by flotation concentration. The inventor has discovered that oxide and carbonate minerals of such metals as copper, lead, silver, arsenic, antimony, mercury, bismuth, tin, cadmium, etc., are superficially converted to sulphides by hydrogen sulphide gas, or water solutions of the same, and that these converted minerals are then readily separated from gangue by oil flotation. In a similar manner, the water-soluble salts of metals are converted to sulphides and made amenable to oil flotation. The process may be applied by grinding the ore in water, treating with hydrogen sulphide gas and agitated with addition of oil. The sulphides float and may be separated from the gangue and recovered for further reduction. (1,094,-760, Apr. 28, 1914.)

Copper Hydrometallurgy and Electrolytic Precipitation.—In patents issued to Mr. GEORGE D. VAN ARSDALE, of East Orange, N. J., the inventor describes his preferred method of roasting, leaching and precipitating copper in ores. When the ore is rosted there should be enough sulphur present to provide at least two parts of sulphur for each part of copper, and the roast conducted so as to give the maximum amount of water-soluble copper compounds. These compounds are leached with acidulated water, the acid for the initial charge being added from an extraneous source. After the cycle of operations is well started the acid can be secured by adding liquor from a preceding operation, being generated in the course of the process. Following the first leaching operation, the ore is washed with a second solution, which is added to the first. If more copper remains, a third wash may be given, the resulting solution being precipitated on iron and run to waste. This waste of solution can be regulated to avoid accumulation of impurities in the circulating mill solution. The original solution obtained is precipitated electrolytically, using sulphur dioxide to prevent polarization by combination with oxygen at the anode, and reduce ferric to ferrous salts. The gas is added to the cells during electrolysis, serving to heat and agitate the solutions.

The hydrogen evolved at the cathode tends to combine with the sulphur dioxide, forming hydrogen sulphide which then reacts to form copper sulphide which will be precipitated with the copper. In order to avoid this, precipitation is continued only until about 80 per cent of the copper in solution is precipitated, after which it is found that further precipitation commences to throw out copper sulphide. With a 10 per cent solution of copper sulphate containing sufficient sulphur dioxide to prevent polarization and reduce ferric to ferrous salts,

10 amperes per square foot at between 0.7 and 1.2 volts is sufficient to effect precipitation of 80 per cent or the copper without throwing out sulphides. The original solution is approximately regenerated and used as before. (1,119,477-8, Dec. 1, 1914.)

Smelting Complex Zinc Ores.—A method of smelting ores containing zinc and other metals such as lead, copper, gold and silver, is patented by Mr. JAMES M. HYDE, of Berkeley, Cal. The fluxed charge of ore is smelted over a bath of slag or matte and out of contact with the gases of combustion used for producing the smelting heat. The zinc is volatilized, the lead reduced to bullion containing some of the precious metals, and the copper recovered as matte containing also some gold and silver. Two types of furnace adapted to the process are shown in vertical transverse section in Figs. 1 and 2.

Referring to Fig. 1, the furnace wall A encloses the heating chamber and retort structure B. The charge within the shaft K and retort B is heated by products of combustion from gas burners G, H and G". The gases entering G and H have no access to the charge within the retort B, and the gas entering G" plays directly on the layer of slag. Arches C permit the fused material to fill the lower portion of the furnace which is provided with tap-holes D, E and F, for slag, matte and metal respectively. Zinc vapors pass off through pipes M to condensers N.

FIG. 1—FURNACE FOR COMPLEX ZINC ORES

In the modification shown in Fig. 2, the ore mixture is delivered through a hopper P' to a tube L' in which is a screw conveyor O' to force the feed into the open-bottomed retort B' extending transversely across the furnace chamber. There may be a number of such retorts suitably supported on a structure provided with open arches as in Fig. 1. The same
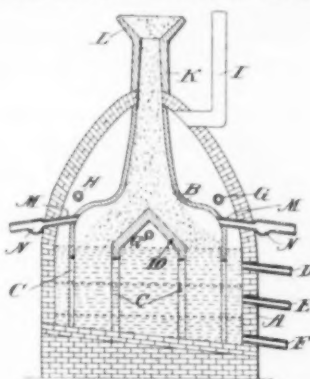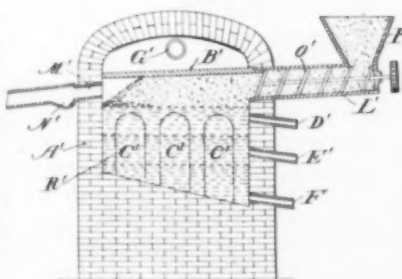

FIG. 2—FURNACE FOR COMPLEX ZINC ORES

tap-holes and condenser are provided.

In operation, the fluxed charge, either briquetted or loose, is fed into the retort where it is heated by the flame outside the retort. Volatilized zinc has a free exit to the condenser, and the fused materials fill the lower part of the furnace, from which valuable products containing the other metals are withdrawn. The process is claimed to offer economy in fuel, labor and mechanical wear and tear, as compared with present practice in retort furnaces, besides offering a possible means of treating mixed ores and recovering practically all the valuable metals. (1,118,012, Nov. 24, 1914.)

Mercury and Molybdenum

Extraction of Mercury.—A process for recovering mercury from its ores and other materials, is patented by Mr. E. BRYANT THORNHILL, of Gray Summit, Mo. The process was developed in connection with the recovery of mercury used for the treatment of high-grade silver ores at the Buffalo mill, Cobalt, Ont., but is appli-

cable to ores. The method is based on the solubility of mercury sulphide in a mixture of alkali sulphide and alkali hydroxide, and the precipitation of metallic mercury from solution by addition of aluminium dust. (1,119,377, Dec. 1, 1914.)

Extraction of Molybdenum.—According to a patent issue to Mr. FREDERICK D. S. ROBERTSON, of Toronto, Canada, the ores of molybdenum can be treated for the production of molybdic tri-oxide by roasting at a temperature of about 800 deg. C. in the presence of an excess of oxygen. The volatilized product is collected in bags. The temperature in the bag-house must not exceed 120 deg. C. when woolen bags are used, or 90 deg. C. with cotton bags.

Data Concerning Platinum, the well known illustrated booklet, published by Baker & Co., Inc., Newark, N. J., has appeared in its thirteenth edition, with numerous new tables, illustrations and matter descriptive of various new appliances of platinum. There are 53 pages of descriptive matter of platinum stills for the concentration of sulphuric acid, platinum dishes, platinum parting apparatus, retorts, crucibles, combustion tubes, muffles, triangles, filter cones, platinum and platinum gauge electrodes, tongs, rods, etc. Concise useful rules follow on the use and care of platinum ware, as well as extensive tables of weights of platinum ware, sheet and foil, conversion tables, sulphuric acid tables, tables of specific weights, boiling points, etc. The whole book comprises 80 pages and is interestingly written and neatly printed and illustrated.

The Scientific Specialties Company is a new corporation with offices and show-rooms at 17 Madison Avenue, New York City. It will be the aim of the company to introduce new specialties in the chemical, metallurgical, physical and bacteriological lines, and to handle import orders for colleges, universities, etc. For this purpose a branch office has been established in Offenbach (Main), Germany. Radium and radium apparatus are one specialty of the firm.

The Industrial Instrument Company, of Foxboro, Mass., has mailed us its illustrated bulletins 86 and 91. Bulletin 86 describes the Foxboro differential recording gauges and orifice meters for measuring the flow of gases, about which we intend to give some further information in a future issue. Bulletin 91 describes the Foxboro recording and indicating dial-type thermometers, with several important recent improvements. Both bulletins contain typical and interesting records from the recorders in actual service.

Under Feed Stokers.—One branch, at least, of the iron industry has been benefited by the present business depression. Since the European war broke out orders aggregating ninety-nine of Hagan American Under Feed Stokers have been received by the George J. Hagan Company, Pittsburgh, Pa., from a number of the oldest companies in America to be used in varied industries from enameling light household utensils to heating heavy blooming mill ingots, so that the George J. Hagan Company has not only been able to keep its full force of employees occupied on full time and pay, but additional assistance in its engineering department has been required. For the Hagan American under feed stokers it is claimed that a cheaper grade of coal and less of it can be used to produce a given number of heat units and that these stokers are especially adapted to heating and annealing furnaces. Among those users who have given new orders recently are the Phillips Sheet & Tin Plate Company, Weirton and Steubenville Plants, National Enameling & Stamping Company, Scullin-Gallagher Iron & Steel Company, Crucible Steel Company of America., etc.

A Norwegian Electric Steel Plant

The Stavanger Electro-Staalverk A.S. has its offices in Stavanger, Norway, and its works at Jörpeland, across the fjord about ten miles east of Stavanger. At Jörpeland cheap electric power is abundant, being purchased from the hydro-electric development company at about $6.00 per mechanical horse-power year.

At Stavanger are some small shipyards, and also firms engaged in breaking up old steel ships. This furnishes a plentiful supply of old scrap steel, which has formerly been shipped to England and Germany,

FIG. 1—GENERAL VIEW OF STAVANGER ELECTRO-STAALVERK CO.

but is now basic material for the flourishing local steel industry. The capitalists of the ship breaking-up business are also largely interested in the electric steel plant.

The photographs show the plant at Jörpeland. Engineer Jacobsen is general engineer for the company. Mr. Th. H. Poulsson the manager of the works and Mr. Svensson metallurgist. The Siemens-Martin furnace has a capacity of four tons, and in it the scrap steel is melted by producer gas made from English coal. In about four hours the melted steel is transferred to a Roechling-Rodenhauser induction electric furnace, and

FIG. 2—CASTING FLOOR

there refined. The composition of the melted open hearth steel and of the refined electric furnace steel are about as follows:

	Open Hearth	Electric
Phosphorus	0.07	0.023-0.010
Sulphur	0.03	0.018-0.008
Carbon	0.10-0.15	As desired.

By adding ferro-alloys, various qualities of special steels, such as high-speed steel and magnet steel, are made.

The large foundry can turn out castings up to 8 tons in weight, by combining a heat in each furnace into one cast. The well-equipped forging plant produces rods and other shapes. Ingots and billets are being shipped

in considerable quantities to Sheffield, England, where they are forged and worked up into the finest "Sheffield Steel." This firm is selling large quantities of steel to England for motor parts for aeroplanes and automobiles; also a special quality of steel for hot-stamping, which is meeting with great success.

FIG. 3—FOUNDRY

The Stavanger Electro-Staalverk made a fine exhibit of its products at the recent Norwegian Centennial Exhibition at Christiania, and received a gold medal.

The success of the company is due to the combination

FIG. 4—FORGING DEPARTMENT

of the cheap supply of scrap steel, melting in the open-hearth furnace, refining in the electric furnace, cheap power, and able engineers and metallurgists in charge of the various departments of its works.

Personal

Mr. **H. F. Grondys**, representative of the Compania Minera de Oruro, Oruro, Bolivia, has been in Salt Lake City investigating metallurgical processes.

Mr. **H. W. Hardinge** has gone to Arizona for a three weeks' tour of the mining camps and to attend the American Mining Congress.

Mr. **Julius W. Hegeler** is president of the newly organized Hegeler Zinc Company, which succeeds to the business formerly conducted under the partner-

ship of Hegeler Brothers. The company operates a zinc smelter at Danville, Ill.

Mr. **James M. Hyde**, of San Francisco, Cal., has been in Colorado on professional business.

Mr. **Woolsey McA. Johnson** has resigned as first vice-president of Johnson Electric Smelting Inc. His resignation will take effect on January 1, 1915. He will be
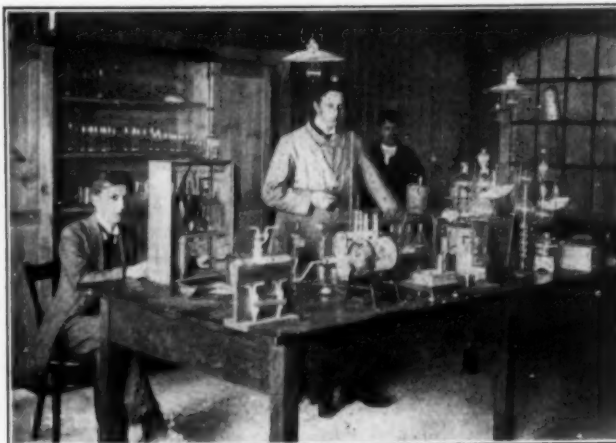

FIG. 5—CHEMICAL LABORATORY

connected with the company for the present in a consulting capacity and will remain a director.

Mr. **A. E. Keller**, of Denver, has gone to Ecuador to revise the mining and metallurgical accounting system for the South American Development Company.

Mr. **John L. Malm** has returned to Denver after a short trip east on professional business.

Mr. **J. H. Polhemus** has resigned his position as assistant to the president of the American Zinc, Lead and Smelting Company to accept a position as assistant manager of mines for the New Jersey Zinc Company.

Mr. **Walter Harvey Weed** has announced the removal of the office of the *Copper Handbook* from Houghton, Mich., to New York City.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

AQUEOUS BATH (ELECTROPLATING) *Continued*

655,111, July, 31, 1900, Andrew Plecher, of Savannah, Georgia.

Relates to portable apparatus for electrolytically decomposing solutions, such as water, into its components, hydrogen and oxygen. The apparatus consists of two parts of a vessel which when assembled is preferably of spheroidal shape. The parts may be of metal, suitably insulated, or of insulating material. The compartment in which hydrogen is evolved has twice the cubic capacity of the oxygen compartment. The compartments communicate with each other near the bottom, and have electrodes of either gold or platinum. Suitable outlets for the gases are provided, and an inlet for the solution to be electrolyzed, which may be dilute sulfuric acid.

664,550, Dec. 25, 1900, Henry L. Hollis, of Chicago, Illinois.

Relates to coating iron or steel objects with a protective coating of oxid of iron, and is an improvement

on his patent 621,084. The improvement consists in using an alkaline electrolyte, such as sodium hydroxid, passing a current therethrough with the iron object to be coated as cathode, whereby it is cleaned, then by a reversing switch changing the direction of current, making the iron object the anode, whereby it is oxidized. The electrolyte of sodium hydroxid has preferably a specific gravity of 1.25 to 1.40, heated to a temperature of 50° C. to 115° C., and with a current strength of 0.005 to 0.3 amperes per square inch of anode surface. The coated articles may then be heated in an annealing furnace for several hours at a temperature of 800° F. to 1400° F., which converts the coating to magnetic oxid.

665,784, Jan. 8, 1901, Henry K. Hess, of Philadelphia, Pennsylvania, Assignor to Herman J. Dercum, Trustee, of same place.

Relates to an apparatus for regenerating the electrolytes of two-fluid primary batteries, and consists of a lead lined tank containing a plurality of vitreous mercury troughs electrically connected as cathode, and a plurality of porous cells between the mercury troughs the porous cells containing lead as shot or scrap, or lead grids, connected as anode. The sulfuric acid electrolyte saturated with zinc is placed in the tank in contact with the mercury, and the reduced chromium solution placed in the porous cells. An electric current is passed which deposits the zinc in the mercury, liberating sulfuric acid, and re-oxidizes the chromium electrolyte. When the charge is regenerated, the mercury trays are removed, the zinc-amalgam pressed out, which may be pressed into amalgamated zinc electrodes, and the regenerated sulfuric acid and chromium electrolyte drawn off.

670,350, March 19, 1901, Botho Schwerin, of Munich, Germany.

Relates to a process of eliminating water or other fluids from solid mineral, vegetable, and animal substances, such as wood-pulp, starch-pulp, ground peat, disintegrated fruits, clay sludge, potatoes or beet-roots reduced to slices or pulp, distintegrated fish or flesh, crushed seeds, and the like, by the action of the electric current. The material to be treated is brought in contact with positive and negative electrodes by placing or moving it between the same while the current is passing. The molecules of water or other fluid diffuse from the solid particles toward the negative electrode where they are allowed to escape to the outside, for instance, by rendering the negative electrode permeable to liquids. The strength of current applied is dependent upon the nature of the fluid to be removed, and must be determined by experiments for each material. Mechanical pressure may be applied to remove some water and thereby reduce the current applied accordingly. For the apparatus used, see patent 670,351.

670,351, March 19, 1901, Botho Schwerin, of Munich, Germany.

Relates to apparatus for carrying out the process of freeing various materials of water described in his patent 670,350. It consists of two concentric cylinders, the inner electrically connected as the positive, and the outer as the negative, the latter being permeable, and may be of perforated sheet, or wire gauze, etc., and having an exterior covering of canvas or cloth. The inner electrode is supported upon a stationary shaft projecting into the apparatus. In the annular space between the electrodes is an insulated spiral, supported upon sleeves on the stationary shaft, and rotated by a pulley mounted upon the outer sleeve, thus moving the material forward. At the discharge end of the apparatus is a spring-pressed disk closing the discharge opening, and arranged to exert pressure against the material to keep it in firm contact with the electrodes and to press out some water through the permeable electrode.

670,510, March 26, 1901, William Friese-Greene, of London, England assignor to the Electrical Inkless Print-Syndicate, Ltd., of same place.

Relates to a method of electrically printing on paper, textile fabrics, etc., words, designs, etc., and is intended to replace the ordinary printing processes using ink or colors. The paper or other fabric is prepared by incorporating with it a photographic developer of the oxybenzene series, such as amidol, metal, or hydroquinon. The chemical may be applied in any suitable way, as by mixing with the paper pulp during the manufacture. The prepared paper is operated upon in a printing press or similar machine, the printing form or type being connected preferably to the negative pole. On passing the current the words or design to be printed appear upon the paper or fabric, and the operation may be performed at a rapid rate.

A variety of colors can be produced by this process, the color varying according to the substance with which the paper is prepared. When amidol is used, the paper should be washed in running water to remove the residual unchanged amidol.

Book Reviews

Coal Gas Residuals. By Fred. H. Wagner. 180 pages, 44 illustrations. Price, $2. New York: McGraw-Hill Book Company, Inc.

This book covers the handling of the gases of distillation to secure tar, naphthalene, cyanogen, ammonia, and benzol.

The treatment is detailed and practical costs of processes being frequently given, with estimates of probable profits.

The theories and processes of Dr. Feld are presented *in extenso,* and constitute a highly valuable source of information on advanced European practise, which American technologists will do well to study and to utilize.

Taken in the whole, it is a first-class book on a very timely subject.

Metallurgy of Copper. By H. O. Hofman, Met.E., Ph.D. Octavo (15 by 23 cm), xiv + 556 pages, 548 illustrations; price, $5. New York: McGraw-Hill Book Company, Inc.

Following his monumental work on general metallurgy, Professor Hofman has made the metallurgical world his debtor by a masterful work on copper. He is completing the series by revising his book on lead, and preparing treatises on gold and silver, and the minor metals.

This is a treatise on copper, for the modern copper metallurgist. In it he will find every branch of the subject considered, with copious references to the literature to enable him to push his studies further than the limits of this book. The compilation has taken an enormous amount of labor, and has been done with discrimination. The typographic errors are extremely few, considering the vast amount of data assembled. Professor Hayward, of Massachusetts Institute of Technology, assisted in the calculations interspersed through the work, which are both interesting and illuminating.

The discussion of bessemerizing of copper matte is very well done, particularly the thermal analysis. Throughout the work, drawings to scale are numerous, and comparative tables of practise in various plants are frequent. The work is everywhere "up to the minute." It is not so well suited for ordinary student reading, being so condensed and encyclopaedic, but will serve them well as a book of reference; it is a true *vade mecum* for the copper metallurgist.